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DEVELOPMENT AND EVALUATION OF COMPOSITE BRAKE PAD USING PULVERIZED SNAIL SHELL AND MUCUNA SLOANEI SHELL AS BASE MATERIALS

[1*]Chima O. M., [1]Simeon B. I. and [2]Onuoha C.

[1]Department of Mechanical Engineering, Michael Okpara University of Agriculture Umudike, Abia State Nigeria

[2]Department of Metallurgical and Materials Engineering, Federal University of Technology Owerri, Imo State Nigeria

[1*] Corresponding author: chimamelford@gmail.com

ABSTRACT

The development and evaluation of a new composite material for automobile brake pad application has been carried out in this study. The brake pad sample was produced with the geometric specification of 504 saloon model. The constituent materials include snail shell with mucuna sloanei shell as filler, iron oxide as abrasive, epoxy resin as matrix, glass fiber as reinforcement and graphite as the friction modifier. The weight composition in grams of the first three constituent materials were kept constant while those of the reinforcement and friction modifier materials were varied at various values of (30 and 25), (20 and 30), (15 and 15) and (5 and 20) grams to develop four different formulations represented as A, B, C and D. These formulated composite mixtures were used to produce the brake pad samples using standard factory procedures. The test samples were thereafter tested for both coefficients of dynamic and static friction, wear rate and hardness. The results obtained showed that formulations A, B, C, and D have values of (0.46 and 0.43), (0.47 and 0.44), (0.42 and 0.37) and (0.43 and 0.40) for static and dynamic coefficients of friction respectively. The wear rate values of 3.5, 3.6, 4.7 and 4.9mg/m were obtained for formulations A, B, C and D respectively while the hardness values of 46, 44, 38 and 30 HRB were noted in the similar order. The optimum value for coefficient of friction was obtained in formulation B while the best wear behavior and hardness value were given by formulation A. It was found that increase in the percentage weight composition of the friction modifier improved the coefficient of friction while increase in the percentage weight composition of the reinforcement material decreased or enhanced the wear rate. The performance evaluation of the formulated brake pad material shows that the properties compare well with the foreign asbestos-based products. Hence, it was concluded that snail shell and mucuna sloanei shell should be used based at the specified composition as base materials for brake pad application.

Keywords: automobile, composite material, properties, formulation and products

1.0 Introduction

Brake pads are important components of the braking system for all automobiles. They are considered as one of the key components that determine the overall performance of the vehicle (Oluwafemi *et al.,* 2019). According to Idris *et al.,* (2012) brake pad is backed with steel plate with the frictional material bonded to the surface that faces the brake disc.

When the brake is applied, friction between the brake pad and the rotating disc which clamp together with each other provides the stopping power that resists the motion of the car. This slows down the vehicle motion and causes the moving vehicle to stop. (Ademu *et al.,* 2011) The brake pad as component of the braking system therefore controls the speed of vehicle. This is achieved by converting the kinetic energy of the car to thermal energy and then dissipate the heat to the surrounding. (Nagesh *et al.,* 2014).

The properties and the performance of an automobile brake pad is a function of both the constituent frictional materials and the formulation used in the development. The constituent materials that are used in the development of automobile brake pad have their own individual functions which include improvement of frictional properties. The formulation of the composite material requires appropriate percentage weight composition ratio in order to achieve optimum properties.

The formulation to be used, requires to be subjected to several tests to determine its wear and friction properties using on–road braking performance test as well as abrasion testing mechanism to ensure that the developed friction pad material meets the minimum requirements of its challenge needed to be solved. (Nagesh *et al.,* 2014), (Osarenmwinda and Bekewei, 2011).

Friction linings for automobile brakes must have high friction coefficient typically within the range 0.40-0.47, necessary over wide variations of temperature, applied speed rate and pressure. This will enable the component to maintain the desired braking characteristics of the vehicle. They should also possess other properties such as low wear rates, low moisture sensitivity, low shrinkage, adequate mechanical strength, high thermal stability, low porosity, good bonding to the back plate among other properties, (Abutu *et al*., 2018).

The development of brake pad material was first traced to Herbert Frood in 1897. (Dareddy *et al.,* 2014). The cotton–

based brake pad material was used for wagon wheels as well as early automobiles and coupled with bitumen solution. This development led to the formation of the manufacturing company known as Ferodo Company, a firm which still runs frictional materials till date.

Later, brake pads consisting of asbestos in the matrix with other ingredients were used in the automobile systems. (Idris *et al.,* 2015). Many different classes of organic brake pads were developed. Class A was made of asbestos which was effective for low temperature application while class B performed better at high temperature but was not durable. (Dagwa and Ibhadode*.,* (2005). Besides these challenges associated with the use of this product, it has been reported that the use of asbestos as a frictional material has harmful effect to human health. Hence, some countries like UK, USA, Colombia, Japan, China and others, have completely banned its use for brake pad application for the risk of causing cancer for factory workers and end users. (Adeyemi *et al.,* (2016).

Therefore, the need to develop asbestos free and ecofriendly materials for brake pad application in local industries becomes an interesting and impressive research area. This led to the use of industrial and agro wastes which have been successfully applied in the production of brake pad composite materials. (Adeyemi *et al.,* (2016). These waste materials are used as local content input. They are converted into useful wealth which is economically advantageous. New materials from agro products are emerging as cheap and is used in the development of brake pad material for commercial viability and environmental acceptability. (Bledzki and Gassan,1999).

Many authors have used utilized these materials to develop high performance brake materials. Koya and Fon, (2011) developed brake pad materials for automobile using standard factory procedure from palm kernel shell and tested their mechanical properties. The results showed that the developed pad has an average hardness of 32.34 HRB and average shear strength of 40.95 MPa. The coefficient of friction of the product was also tested and the result indicated that the pad possessed a frictional coefficient of 0.43. The result showed that the coefficients of friction of palm kernel shell on metal surfaces are in the range of 0.37–0.52. However, friction coefficient that falls within the range of 0.30–0.70 is desirable when using brake pad material. (Roubicek *et al.,*2008).

In the quest to replace asbestos-based brake pad, several other agro waste sources have been sourced and used locally to balance this effect. Bashar *et al*. (2012) and Darlington *et al.* (2015**)** conducted a study to find a possible replacement for asbestos, using coconut shell powder to develop brake pad material. This material was mixed with other ingredients such as catalyst, epoxy resin, cast iron fillings, silica, and accelerator in the former and coconut shell powder and palm kernel shell as reinforcement materials, graphite as lubricant, polyester resin as binder material, carbides and metal chips as the abrasives in the latter. The results obtained showed that developed samples have density which falls between 2.55–2.78 g/cm^3, wear rate of 0.2007–0.2733 g/min, percentage water absorption of 0.0399–0.0522% and hardness of 3.00-3.41. Yawas *et al.,* (2016) and Onyeneke *et al*., (2014) developed an asbestos–free brake pad and analyzed the microstructure of the developed friction materials using scanning electron microscope (SEM). Using periwinkle shell as reinforced material, the mechanical, physical and tribological properties of the periwinkle shell-based brake pads were also investigated and compared with the properties of asbestos – based brake pads. The results indicate that the microstructures of the developed samples showed a homogeneous distribution, as the periwinkle shell particles sieve size decreases. The properties were reported to compare well with asbestos-based brake pad.

Other local agro wastes used either in one or in combination for the development of automobile brake pad by previous authors include palm ash, rice husk and rice straw, among others. (Ruzaidi *et al.,* (2011); (Ibrahim, 2009)

Based on the previous studies, it was found that there is need to exploit other nonbiodegradable agro wastes such as snail shells for brake pad production. These wastes are very difficult to dispose. They liter the environment and constitute to land pollution problem. The use of these agro waste materials for development of industrial products has a lot of advantages. It will utilize the redundant waste for wealth creation, increase the use of local content to reduce manufacturing cost and also clean up the environment.

Besides, optimum performance is expected from every engineering product, therefore there is need to tackle the challenge of determining the appropriate formulation of the constituent materials that yields the best combination of the braking characteristics.
Therefore, this study sought to use local agro wastes such as snail shells and mucuna sloanei shells as the base materials with other ingredient materials in different formulations to develop brake pad. More also, determine the braking properties and compare their performances with the asbestos-based and other existing ones.

2. Materials and Methods

2.1 Materials

The various ingredient materials used for the development of the composite were epoxy resin with hardener, shells of snails and mucuna sloanei, glass fibre, graphite and iron oxide. The listed materials functioned as matrix, filler, reinforcement, friction modifier and abrasive respectively. The matrix mixing ratio of 1:3 was used for epoxy resin to hardener.

2.2 Methods

2.2.1 Development of the Composite Brake Pad

The base materials (snail shell and mucuna Sloanei shell) were sun dried. The shells were thereafter separately crushed and ground using ball milling to develop fine particle size suitable for the application. The ground materials were subjected to sieve analysis using sieve of 100μm size. The choice of the sieve size was based on the recommendation of standard organization of Nigeria. (Amaren, 2016). The two filler materials were mixed at equal proportion by weight. The weight compositions of both abrasive, matrix and filler materials were kept constant while those of the reinforcement and friction modifier were varied as presented in Table 1 to develop four various formulations made for the production of the brake bad. The weight compositions of the two constituent materials were varied in the formulations in order to determine the best mixture ratio which could yield the optimum properties required for brake pad application.

Table 1 Percentage Weight Composition of the Formulated Composite Mixtures

Formulated Sample	Abrasive	Matrix	Filler	Reinforcement	Friction Modifier
			weight composition in grams		
A	20	70	100	30	25
B	20	70	100	20	30
C	20	70	100	15	15
D	20	70	100	5	20

The mould was made of metal sheet according to the required geometric shape of the product. The determined quantities of the ingredient materials in each of the four formulations were measured out. The composite mixture was thoroughly stirred and blended to get a homogeneous mixture which was poured into the various moulds. The composite mixtures were compacted using improvised device. Sanding machine was used to level and trim the surface of the compacted mixture to acquire a uniform thickness to produce the sample shown in Figure 1. The composite paste mixture was allowed to cure within 1 hour and to develop full strength within 7 days as reported by previous related literatures. (Adeyemi *et al.,* (2016). When the strength developed fully, the samples were then subjected to various tests including coefficient of dynamic and static friction, wear rate and hardness.

2.2.2 Determination of Mechanical Properties

The test samples were tested for coefficient of dynamic and static friction, wear resistance and hardness using standard experimental procedures.

The Coefficient of Dynamic and Static Friction

The coefficient of friction was tested using ASTMD1894 standard with horizontal plane method.

The surface of the samples was first ground using grinding machine and then perforated to get a string rope tied to it during the test. The brake pad was weighed and the mass was recorded as M_1. It was placed on a plane in the horizontal position. A cord of string was fastened to the brake pad to the pulley via a hanger. The load on the hanger was gradually increased until the brake pad slide at a constant velocity. A slight push was added to set the object in motion. The value of the load which included the mass of the hanger was recorded as M_2. The procedure was repeated using different samples. The appropriate hanging weight in each case that pulled the brake pad sample at constant velocity were recorded. The coefficient of dynamic friction μ_d was computed as

$$\mu_d = \frac{M2g}{M1g} \quad (2.1)$$

g is acceleration due to gravity.

The same procedures were repeated for static coefficient but in this case, there was no external force applied, hence the object was sliding on the friction plane due to load of the hanger.

Wear Rate

The wear rate of the brake pad samples was tested using a tribor-testing machine which is designed to determine the wear rate at a constant load application for a given time duration. The initial weight of the specimen was measured and recorded as W_1. The specimen was fixed to the rotary disc of the machine with a nut while two emery wheels at the upper arm of the machine were allowed to have direct contact with the specimen. The machine was operated as the disc rotated at a speed of 2500 rpm with contact pressure of 38.89KN/m^2 within the time duration of 1000 seconds.

The contact made by the two emery wheels on the specimen during the rotation caused the specimen to wear. At the end of the predetermined time, the specimen was removed and reweighed to determine the new weight recorded as W_2. The weight loss was calculated as $\Delta W = W_1 - W_2$ while the wear rate was computed as

$$\text{Wear Rate} = \frac{W1 - W2}{S} = \frac{\Delta W}{2\pi NDt} \quad (2.2)$$

Where: S = Sliding distance
N = Radial speed
D = Disc diameter
t = Time used to expose the specimen to wear

Hardness

Brinell hardness testing machine with a 20 mm diameter steel ball indenter was used to determine this property. A load of 3000kg was applied for a period of 15 seconds. The hardened steel ball penetrated the specimen and the diameter of the indentation was measured. The Brinell hardness number was computed as the value of the load divided by the surface area of the indentation, which is mathematically represented as;

$$\text{Hardness } H_B = \frac{2P}{\pi D[D - \sqrt{D^2 - d^2}]} \quad (2.3)$$

Where P is the applied load (kg), D is the diameter of the indenter and d is the diameter of the indentation (mm).

3. Results and Discussion

3.1 Results

The results obtained in this work are shown in figure 1 and in Table 2 – 5. Figure 1 shows the samples of the formulated brake pad. Tables 2 and 3 show the results obtained for the test of coefficient of static and dynamic friction respectively. Table 4 shows the results for wear rate while Table 5 indicates the results for hardness test. These results show the effect of the percentage composition of the constituent materials on the frictional properties of the various formations.

Figure 1. Samples of the formulated composite brake pad

Table 2: Co-efficient of Static Friction for the Formulated Brake Pad and Asbestos-based Samples

Formulated Sample	Load	Sliding mass	Co-efficient of Static friction (μ_s)
A	0.65	1.4	0.46
B	0.80	1.7	0.47
C	0.50	1.2	0.42
D	0.65	1.5	0.43
Asbestos-based sample			0.30 – 0.40

Source: Adeyemi *et al*.(2016)

Table 3: Co-efficient of Dynamic Friction for the Formulated Brake Pad and Asbestos-based Samples

Formulated Sample	Load (kg)	Sliding mass (kg)	Co-efficient of dynamic friction (μ_d)
A	0.60	1.4	0.43
B	0.75	1.7	0.44
C	0.45	1.2	0.37
D	0.60	1.5	0.40
Asbestos-based sample			0.30 – 0.04

Source: Adeyemi *et al*.(2016)

Table 4: Wear Rate of the Formulated Brake Pad and Asbestos-based Samples

Formulated Sample	Wear Rate (mg/m)
Sample A	3.50
Sample B	3.60
Sample C	4.70
Sample D	4.90
Asbestos-based sample	3.80

Source: Oluwafemi *et al.*(2019)

Table 5: Hardness Values of the Formulated Brake Pad and Asbestos-based Samples

Formulated Samples	Hardness (HRB)
Sample A	46
Sample B	44
Sample C	38
Sample D	30
Asbestos-Based sample	101

Source: Oluwafemi *et al*.(2019)

3.2 Discussion

3.2.1 Coefficient of Friction

From the results obtained in the test for coefficient of friction, it was observed that the range of values of 0.42 – 0.47 and 0.37 – 0.44 were obtained for coefficient of static and dynamic friction respectively. This shows that generally, values of coefficient static friction are more than those of dynamic friction.

The coefficient of friction is the best test that helps to measure the stacking ability of the material's surface. It contributes to prevent the accidents that can occur due to friction in transportation or movement of materials.

The respective optimum values of 0.47 and 0.44 for static and dynamic friction were observed in formulation B while minimum values of 0.42 and 0.37 were obtained in formulation C. The formulations of A and D yielded values of 0.46/0.43 and 0.43/0.40 respectively. The lower coefficient of friction indicates that the material's surface is less resistant to sliding motion. The resistance to sliding motion of a material relative to one another could be traceable to the percentage composition of the various constituents of the composite material. It could also be attributed to uneven thickness of the surface and other sliding properties of the surface such as the pair of surfaces in contact and the materials used.

It was therefore noted that the effect of the percentage composition of the composite material constituents had significant effect on the properties of the composite brake pad. The sample that has the highest weight composition of the friction modifier of 30grams yielded the best coefficient of friction value as noted in formulation B. Other factors like the contact surfaces and the nature of the materials must have influenced the behavior of the materials. Notwithstanding, it was noted that the values of the coefficient of friction obtained in the formulations were better than those of the asbestos-based brake pad recorded as 0.4 (Adeyemi, *et al*., 2016) (Ademoh and Adeyemi, 2015).

3.2.2 Wear Resistance

The results obtained in the wear resistance test shown in Table 3 indicate that the wear rate of formulations A, B, C and D were 3.5, 3.6, 4.7 and 4.9mg/m respectively. Low value of the wear rate indicates a good wear behavior of the material. The optimum values of this property were obtained in formulation A, followed by formulation B. The excellent wear behavior is attributed to the higher weight composition of glass fiber-reinforcement of 30 and 20grams respectively. The reinforcement material reduces the softness of the composite material and decreases the wear factor. This makes the composite material suitable for wear resistant applications.

The comparison of the wear rate of the conventional asbestos-based brake pad with the formulated samples as reported by Oluwafemi *et al*., (2019) shows that snail shell-based brake pad has better wear behavior.

3.2.3 Hardness

The results obtained for the hardness test show that hardness values of 46, 44, 38 and 30 HRB were obtained for formulations A, B, C and D respectively. Hardness is a measure of resistance to indentation. It is related to wear rate. It has been reported that hardness increases as particle size decreases. (Abutu *et al*., 2018). It therefore implies that higher hardness value could be obtained when the particle size is decreased below the size used in this study.

4. Conclusions

In this study, composite frictional materials have been developed using snail shells and mucuna sloanei shell as the base materials with varied composition of other ingredient materials. In view of this, the suitability of the formulated composite for brake pad application has been established.

It was also found that higher percentage weight composition of the friction modifier yielded higher values of coefficient of friction while higher quantity of the reinforcement materials improved the wear behavior and hardness. Formulation A and B gave good frictional characteristics recommended for brake pad application. The performance evaluation of the formulated brake pad material shows that the properties compare well with the asbestos-based products. The usefulness of the agro wastes has been established. Hence, opening up the opportunity for their exploitation in for development of brake pad.

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