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ORIGINAL RESEARCH ARTICLE

EVALUATION OF SHEANUT SHELL-REINFORCED AUTOMOTIVE BRAKE PAD

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ABSTRACT

For over a century now, asbestos has been used as friction material in the manufacture of brake pads but its use is currently been avoided due to its carcinogenic nature and potential to cause cancer. This study is focused on development of a new brake pad using sheanut shell (SNS) which is an eco-friendly material as the reinforcement and epoxy resin as the binder. Other constituents used are calcium carbonate ($CaCO_3$), graphite and aluminium oxide (Al_2O_3). Five compositions were formulated with the epoxy resin and reinforcement varied at interval of 5 wt% while $CaCO_3$, graphite and Al_2O_3 remain constant at 30, 10 and 10 wt% respectively. The developed brake pads were subjected to compressive, abrasive and water absorption tests while their densities were also measured. The results showed that the compressive strength, abrasive strength and the density of the samples decreased as the reinforcement content increased while the water absorption rate increased as the reinforcement content increased. The value of the compressive strength ranged from 64.88 – 93.04Mpa, wear rate from 3.13 – 6.25mg/m, water absorption from 0.899 – 2.722% and density from 0.764 – 1.487g/m^3. The result of this research indicates that SNS particles can be used as a replacement for asbestos in brake pad production.

1.0 Introduction

Brake pads are important parts of braking system for all types of vehicles using disc brake. The importance of brake pad is to convert the dynamic energy of the vehicle to heat energy by means of friction and dissipating the heat to the surrounding environment (Maleque et al., 2012). Different types of brake materials are used in different machines. They are usually classified into four components namely binders, fillers, modifiers and reinforcements (Dagwa and Ibhadode, 2006; Blau, 2001; Maleque et al., 2012; Umamaheswara, 2015). The brake pads generally consist of asbestos fibres embedded in polymeric matrix along with several other components. The use of asbestos fibers is being avoided due to its carcinogenic nature (Yuvaraj and Jeyanthi, 2015). Despite its good properties, asbestos is being withdrawn from all the applications, where there is a possibility of alternate material for making brake pad that will not pose health risks leading to diseases like asbestosis, mesothelioma, lung cancer and other cancers (Dagwa and Ibhadode, 2006; Mathur et al., 2004; Anon, 2004; Norton, 2001; Rinek and Cowen, 1995). Although the use of asbestos for brake pads has not been banned, much of the brake pad industry is moving away

from asbestos brake pads because of concerns regarding airborne particles in the factories and disposal of wastes containing asbestos (Aigbodion et al., 2010).

Several researches have been carried out in the area of development of asbestos-free brake pads. The use of coconut shell, palm kernel shell (PKS) have been investigated (Dagwa and Ibhadodo, 2006; Dagwa and Ibhadode, 2005). Researches all over the world are focusing on ways of utilizing either industrial or agricultural wastes as a source of raw materials for composite development (Lemon et al., 2008). These wastes utilization will not only provide more economic benefit, but may also result to foreign exchange earnings and environmental sanitation (Yuvaraj and Jeyanthi, 2015). Sheanut shells are wastes resulting from Shea nut consumption were collected from the refuse dumped cite in Kodan village, Niger State. The presence of hard elements like silicon, calcium, iron, carbon and magnesium which are equally found in asbestos suggests that sheanut shell can be used as a reinforcement material for brake pad production as similarly observed in the work of Ikpambese et al., 2014. The application of sheanut shell as a reinforcement material will not only eradicate the health risk posed by using asbestos but also move Nigeria ahead towards realization of her dream of increasing local content in automobile industry.

2. Materials and Methods

2.1 Materials

Materials used in this study consist of the main components of the brake pad namely: Sheanut Shells (SNS) as the reinforcement and epoxy as binder, $CaCO_3$ as filler and graphite (Figure 1B) and Al_2O_3 as the frictional additives. The reinforcement is to improve the mechanical properties of the composites, the binder maintains the pad's structural integrity under mechanical and thermal stresses, the filler material improves the manufacturability of the brake pad while the frictional additives modify the coefficient of friction and the wear rate. Other materials used include sodium hydroxide and distilled water. These materials were almost the same with the materials used by Bala et al. (2016).

2.2 Methods

2.2.1 Preparation of the Raw Material (Reinforcement)

The SNS were collected and soaked in a solution of water and sunlight detergent for 30 minutes for easy removal of dirt and other contaminants. The SNS were thereafter washed properly and sun dried to constant weight after which it was ground using milling machine. This method is in line with the one adopted by Bala et al. (2016). The ground SNS (Figure 1A) was treated with 10% Sodium Hydroxide (NaOH) and sun dried to constant weight. This treatment is to increase the bonding ability of the reinforcement with the resin (Pujari et al., 2014). The treated reinforcement was then sieved using 150µm mesh.

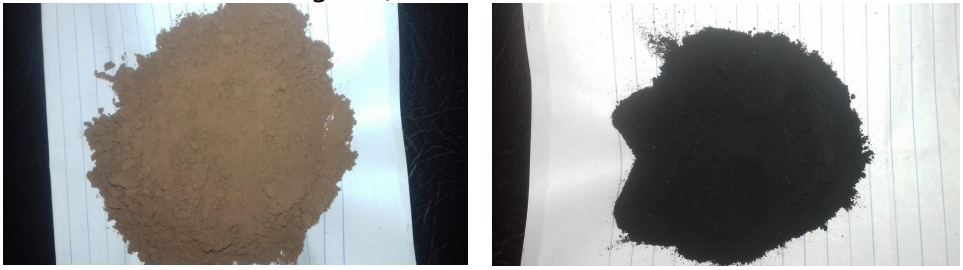

Figure 1: Ground SNS (A), Ground graphite (B)

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2.2.2 Formulation of the Brake Pad Compositions

The formulation of the brake pad compositions which is in line with the approach of Bala et al. (2016) is shown in Table 1.

Table 1: Weight Percent Compositions of the Brake Pad

Sample No	1	2	3	4	5
Resin	40	35	30	25	20
SNS	10	15	20	25	30
$CaCO_3$	30	30	30	30	30
Graphite	10	10	10	10	10
Al2O3	10	10	10	10	10
Total	100	100	100	100	100

2.2.3. Production of the Brake Pad Samples

Production of automotive brake pad consists of a number of unit operations including mixing of its components, hot pressing, cooling, post curing and finishing (Gurunath and Bijwe, 2008; Koya and Fono, 2009).

Different samples of ground SNS, calcium carbonate, graphite and aluminium oxide were thoroughly mixed in a container to obtain the percentages indicated in Table 1, following the method of Abutu et al., 2018. The epoxy resin + triethylenetetramine hardener was properly mixed in a separate container, poured into the first mixture and then mixed thoroughly for five minutes to obtain a homogenous mixture (Yawas et al., 2016). This homogenous mixture was then charged into a metallic mould lined with aluminium foil for easy removal of the cast. The samples were kept under the hydraulic press at a pressure of 11 N/mm^2 and temperature of 120°C for 10 min. The cast samples were post cured in an electric oven at 150°C for 2 h. This was similar to the method adopted by Yawas et al. (2016) and Mathur et al. (2004). Figure 2A, B and C shows the mixing of the constituents, the samples produced and the sheanut shells respectively.

A B C

Figure 2: Mixing of the constituents (A), Produced Samples (B), Sheanut Shells (C)

2.2.4 Characterization of the Produced Brake Pads

The produced brake pads were characterized by subjecting them to density measurement, compressive, absorption, abrasive and thermal conductivity tests using standard methods and procedures.

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2.2.4.1 Density

Density depends on the constituents of the brake materials formulation (Talib 2007; Nirmal et al., 2011). The true densities of the specimens were determined using Archimedes's principles. The volumes of water in the cylinder before and after immersion of the specimens were taken and their difference gives the volume of the specimen. The densities of the specimens were determined by dividing the mass of the specimen before the immersion by the difference in the volumes of the water (Egeonu et al., 2015). That is, by weighing them on a digital weighing machine and measuring their volumes by liquid displacement method (Aigbodion and Akadike, 2010). The density was calculated using the formula given by Cracium et al., (2017):

$$P = \frac{m}{v} \quad (1)$$

where:

P = Density in g/cm^3

m = Mass in g

v = Volume of liquid displaced in cm^3

2.2.4.2 Compressive Strength

Specimens were subjected to compressive test using Enerpac Universal Hydraulic Digital Material Testing Machine 100KN, Norwood Instrument Ltd, New Mill Road Houley, Hundersfield, Great Britain HD9 6QD shown in Figure 3(A) in accordance with ASTM D3410/D3410M. The specimens were cut to a dimension of 20 × 20 × 10 mm in order to conform to the specification of the instrument used. These specimens were loaded manually continuously until failure occurred. The load at failure was digitally displayed and recorded. This was in accordance with the method adopted by Aigbodion and Akadike (2010). The compressive strength was calculated using the formula:

$$\sigma c = \frac{P}{A} \quad (2)$$

where:

σc = Compressive Strength in MPa

P = Applied Load in N

A = Cross Sectional Area in mm^2

2.2.4.3 Water Absorption Test

The 24-h water soak test was carried out to determine the water absorption behaviour of the brake pads produced. The samples were oven dried at 70°C for 1 h and their weights measured. After 24 h of submersion in water at 30°C according to Idris et al. (2015), the specimens were weighed after the excess water had drained off. The absorption was calculated using the given formula (Smales, 1995; Talib, 2007; Edokpia et al., 2014):

$$Absorption\ (\%) = \frac{W_1 - W_o}{W_o} \times 100\% \quad (3)$$

where:

W_1 = weight after immersion in g ; W_o = weight before immersion in g

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2.2.4.4 Wear Rate

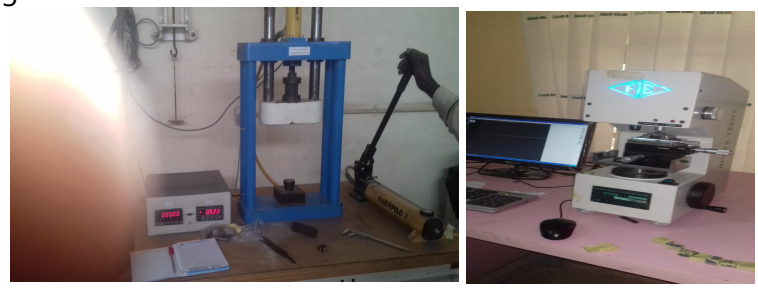
An apparatus known as "Tribometer", Anton Paar, Switzerland shown in Figure 3(B)was used to investigate the dry sliding wear rate of the sample in accordance with ASTM: G99 – 05 standards (Idris et al., 2015). This equipment and methods used to examine the worn surface include optical microscopes, scanning electron microscopes, optical interferometry and mechanical roughness testers. The result of the wear test using this apparatus is always displayed on the screen of the computer attached to it.The samples dimensions were 25 mm in diameter and 5 mm in thickness. The difference in weights of the samples before and after test gives the wear of the samples. Loss in weight was converted to wear rate using the formula given by Aigbodion and Akadike (2010):

$$Wear\ rate = \frac{\Delta w}{s} \quad (4)$$

where

ΔW = difference in weight before and after test in mg

s = sliding distance in m.



A B

Figure 3: Compression tester (A), Tribometer (B)

3. Results and Discussion

3.1 Characterization of the Produced Brake Pads

3.1.1 Density

Figure 1 shows the variation of density with reinforcement content in the composite samples. It was observed from the result that the density of the composite decreased as the reinforcement content increased. This according to Idris et al., (2015) may be attributed to the reduction in the interfacial bonding between the reinforcement and the resin. This result was in agreement with the previous study of Bala et al. (2016). The values obtained were between 0.764 – 1.487 g/cm^3 which are within the recommended values for the application of brake pad given by Kim et al. (2003).

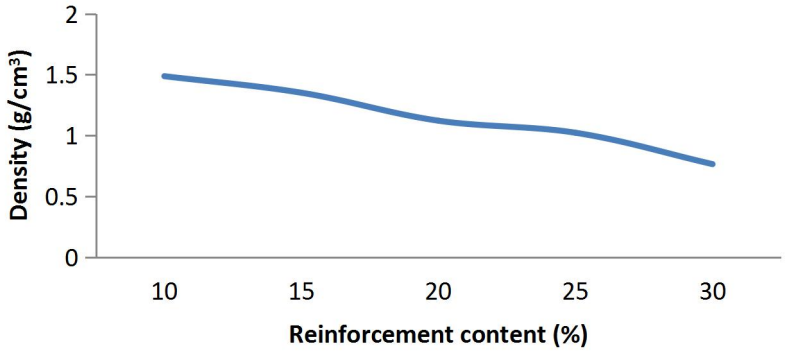


Figure 4: Variation of Density with Reinforcement Content

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3.1.2 Compressive Strength

Figure 2 shows the effect of the reinforcement content on the compressive strength of the composite. It was observed from the result that the compressive strength decreased with increase in reinforcement content. This gradual decrease may be attributed to the decreasing surface area and pore packaging capability of the reinforcement in the resin as the reinforcement content is increasing (Aigbodion et al., 2010). The values of the compressive strength obtained are between 64.88 and 93.04 MPa. These values are within the range of the values obtained in the work reported by Idris et al. (2015).

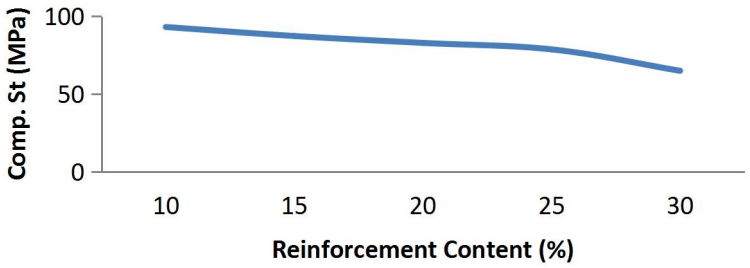

Figure 5: Variation of Compressive Strength with Reinforcement Content

3.1.3 Water Absorption

Figure 3 depicts the variation of the absorption rate with the reinforcement content in the composite. It can be seen from the result that the absorption rate increased as the reinforcement content increased. This may be attributed to the increase in pores as the reinforcement content increased which could be due to reduction in interfacial bonding between the reinforcement and the matrix. This result is in agreement with that of Bala et al., (2016). The values obtained were within the range of 0.899 – 2.722 %. These values are also within the range of the values obtained in the work of Bala et al., (2016).The less the value of the absorption rate, the better the material for brake pad production under study.

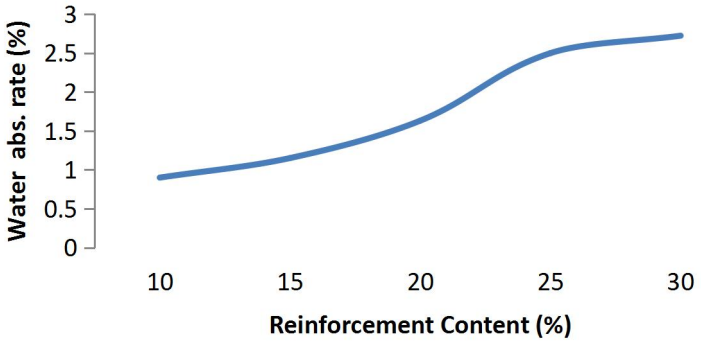

Figure 6: Variation of Water Absorption Rate with Reinforcement Content

3.1.4 Material Wear

The variation of wear rate with reinforcement content of the composite is shown in Figure 4. It is observed from the result that the wear rate reduced as the reinforcement content increased. This may be due to better interfacial bonding between the reinforcement and the matrix causing good surface property. This result is in agreement with the research work of Idris et al. (2015). The values of the wear rate of this work ranges from 3.13 – 6.25 mg/m.

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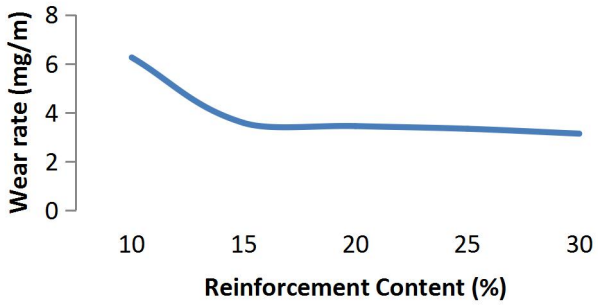

Figure 7: Variation of Wear Rate with Reinforcement Content

3.2 Comparison of SNS Based Brake Pad with other Experimental Brake Pads

Table 2 below shows the comparison between the SNS based brake pad and other experimental brake pads.

Table 2: Comparison of SNS Based Brake Pad with other Experimental Brake Pads

Properties	Commercial Asbestos Based Brake Pad	Palm Kernel Based Formulation	Bagasse Based Formulation	Carbonized Banana Peels Based Formulation	SNS Based Formulation
Density (g/cm^3)	1.89	1.65	1.43	1.20	0.764-1.487
Water Absorption (%)	0.9	5.03	3.48	3.0	0.899-2.722
Compressive Strength (MPa)	110	103.5	105.6	61.20	64.88-93.04
Wear Rate (mg/m)	3.8	4.40	4.20	4.67	3.13-6.25

Table 2 shows the density, water absorption, compressive strength and wear rate values for asbestos, palm kernel, bagasse, carbonized banana peels and SNS based brake pads (Ibhadode and Dagwa, 2008; Aigbodion et al., 2010; Idris et al., 2015). Though the values for commercial asbestos based are taken as the standard, other brake pad formulations shown in the table cannot be out of place since they also have some properties that are better than that of asbestos based. For example, the density of the SNS based (1.487g/cm^3) is less than that of the asbestos based (0.9g/cm^3) while other properties are in close agreement.

4. Conclusion

From the results obtained, the values of the compressive strength, wear rate and the density were observed to be decreasing with the increase in reinforcement content while the water absorption rate was increasing with the increase in reinforcement content. However, the values obtained for all the tests carried out can be comparable to the values of the commercial asbestos based and other experimental brake pads. Hence, the shea nut shell can be used as a replacement for asbestos in the production of brake pads.

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