# Quality Characteristics of Commercially Available Brake Pads for Light Weight Vehicles in Nigeria Market

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## Abstract

Many experimental studies on the different compositions of brake pads have been carried out with the goal of providing sufficient wear resistance, stable friction and acceptable environmental conditions. However, the variation of the coefficient of friction and performance properties depends on it materials. The presence of different types of brake pads in the Nigerian market today makes it imperative to make a clear distinctions with regards to quality and performance. This study investigate the quality characteristics of commercially obtained brake pad for light weight vehicles with respect to their physical and mechanical properties. The vehicles considered for this study were those with gross weight of between 1500 – 3500 Kg in Ilorin. The brake pads of three different vehicle brands were procured and labelled A, B and C respectively. The properties examined were Brinell hardness, tensile strength, compressive strength, impact strength and coefficient of friction by following standard test in each case. The results obtained showed that at 3000 Kgf, sample A, B and C has Brinell hardness values of 117.15, 106.68 and 103.22 respectively. Sample C has the highest yield force under tensile at 815.03 N followed by sample A at 520.87 N and sample B at 426.51 N. Under compression, sample B has the highest yield force of 32.46 KN while sample A has 17.68 KN and sample C recorded 14.59 KN. The three test samples showed impact strengths of between 69 – 69.17 J with sample B having the highest impact strengths of 69.17 J. The coefficient of friction obtained ranges between 0.32 – 0.34. The results indicate non-uniformity in brake pads composition in the study area and the local authority involved with standardization needs to enforce strict adherence to standards.

## Keywords

Brake pads; Light weight; Lining materials; Mechanical properties; Physical properties

# 1. Introduction

The braking system happens to be an essential component for the purpose of safety and controlled performance in the design of automobiles. (*Dagwa et al 2006; Achebe et al., 2018*) The presence of this component in automobiles provides assistance for safe reduction in the speed of automobile vehicles and subsequently bringing the vehicle to a halt as the case may be. (*Elakhame et al. 2014, Nagesh et al 2014*). The principle of operation of brake pad is based on the transformation of energy in which the kinetic energy of a moving vehicle is been transformed into thermal energy which results in either retardation of the vehicle or bringing the vehicle to a halt. (*Surojo et al. 2014*)

The materials used in the formulation of brake pads play significant role in deciding the suitability and their respective individual properties combine to determine the properties possessed by the brake pads. (*Darius et al 2007*). Since brake pads lining material is a crucial component from the safety point of view, materials used for the brake systems should possess stable frictional and wear properties under varying conditions of load, speed and environment (*Riyadh et al. 2012;* Akıncıo˘glu, *et al.*, 2018).

Due to these varying conditions, different sliding parameters that contribute to wear and consequently vehicle brake failure have been investigated over the years (Hasan and Ilyas 2018; Akıncıoglu *et al.*, 2018). Hasan and Ilyas (2018) reported brake performance is affected not only by the materials and vehicle hardware design, but also, importantly, by driver behaviour, vehicle usage, the state of adjustment of the brake system, and the overall environment in which the vehicle is driven. One of the most manifested causes of failure of the brake system of an automotive is the use of substandard brake pads (Nwufo et al., 2013). The presence of different types of brake pads in the Nigerian market today makes it imperative for one to make clear distinctions with regards to quality and performance. The important physical properties of interest to the vehicle users include the wear rate and effectiveness of the brake pads. Friction brake materials using Cantala fibers were developed to investigate their frictional characteristics. The volume fraction of the fibers in the specimens were varied from 0%, 4%, 8% to 12% of the total composition of the friction brake material. The frictional characteristics of the specimens were evaluated using pin-on-disc tribometer. The result shows increase in contact pressure caused the coefficient of friction to increase, while the increase in sliding speed caused a decrease in the coefficient of friction (Maulana et al., 2018). Borjesson et al. (1993) reported that consumer usually demanded for durable, safe and low cost brake pads with efficient properties mention above. In order to be able to ensure safety, wear and effectiveness tests could be conducted on the various locally available brake pads in the Nigerian market. This work was embarked on materials characteristics in brake pad for light weight vehicles to provide useful information on the cause of wear of vehicle brake pads lining materials in the selected vehicle. The objective of this study is to analyse the physical and mechanical properties of brake pads for different light weights vehicles.

## 2. Materials And Methods

The brake pads employed for this research are those used in light weight vehicles with gross weight of 1500 – 3500 Kg and the specification is as stated by Nigeria Industrial Standard (NIS 323: 1997) for brake pads and linings.

### 2.1. Materials

The materials used for this experiment were procured from the local market in Nigeria and were subjected to composition analysis using ARL 4460 Optical Emission Spectrometry equipment and the result is presented in Table 1 for the composition that include Iron (Fe), Carbon (C), Silicon (Si), Vanadium (V) Tungsten (W) and Tin (Sn)

Table 1 – Elemental composition of brake pads lining materials used for the study

| S/N | Test Specimen | % Composition | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fe | C | Si | V | W | Sn |
| **1** | SA | 26.45 | >59.39 | 0.39 | 0.48 | 9.83 | 9.83 |
| **2** | SB | 0.41 | >94.054 | >4.65 | 0.00 | 0.12 | 0.01 |
| **3** | SC | 0.87 | >89.20 | >9.25 | 0.00 | 0.11 | 0.04 |

## 2.2. Methods

The following physical and mechanical tests were carried out on the brake pads.

### 2.2.1 Sample Preparation

The sample A, B and C is the Honda Accord EX, Toyota Carina XL and Mazda CX brake pad respectively as shown in Figure 1. The samples were carefully mounted on a bench vice and the brake pads lining materials were carefully removed from the metallic back plates using hacksaw. Afterwards, the brake pad lining material was prepared for the property tests according to the dimension of the products obtained.

Figure 1: Test specimens for Different Light Vehicles

### 2.2.2 Brinell Hardness

Brinell hardness testing machine in Figure 2 with model number EEDB00006/13 was used to test for the resistance of the specimen to indentation. A hardened steel ball of 10mm indentation diameter was pressed into the test specimen under a constant load of 3000 Kgf for a dwell time of 15 seconds. The indentation created was measured using a micrometer screw gauge across two different directions with the mean value substituted for in the formula for Brinell hardness number (BHN) (*Elakhame et al. 2014*)

$$BHN = \frac{2P}{\pi D\left(D-\sqrt{D^2-d^2}\right)} \quad (1)$$

Where P is the Applied load (Kgf), D is diameter of hardened steel ball (mm) and d is Diameter of indentation created (mm)


Figure 2: Setup for the Brinell hardness test

### 2.2.3 Izod impact test

Avery Denilson Impact testing equipment in Figure 3 with a capacity of 150 J and an impact velocity of 3.65 m/s was employed for the test. According to ASTM E23-2013 test standard, the test samples were prepared into 64 x 12 x 3.2 mm dimension with a 2 mm deep notch at the centre. Each of the test specimens was firmly fixed with the notched area positioned in the opposite direction of the falling hammer. The hammer was released at maximum load of 150 J to create an impact on the test specimen and the result of the impact was read on the equipment scale.

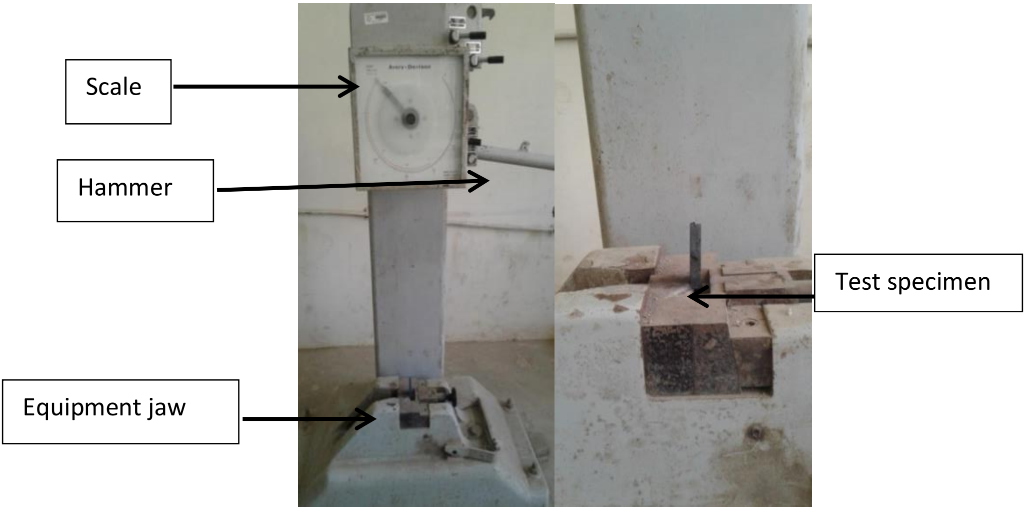


Figure 3: Setup for the Izod impact test


Figure 4: Setup for the tensile test

### 2.2.5 Compressive strength

The test specimens were prepared into a determined shape of 10 mm x 10 mm x 30 mm according to ASTM E9-2013 test standard after which it was placed between the jaws of the testometric Universal Testing Machine with a capacity of 50 KN as in Figure 5. An initial force of 5 KN was applied on the specimen and was gradually increased until the material finally yielded under load.

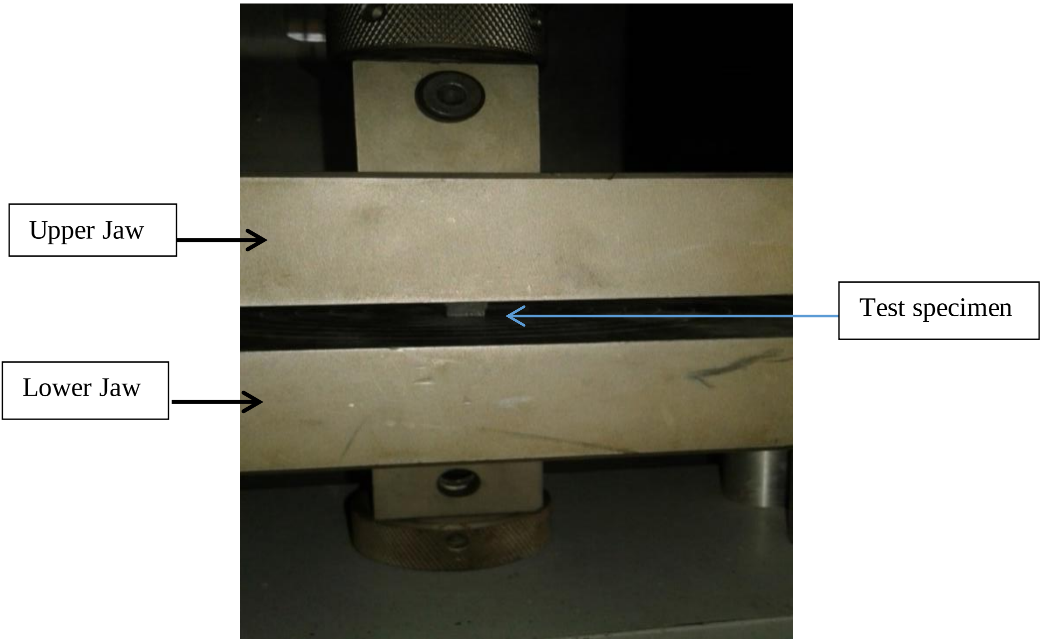


Figure 5: Setup for the compression test

### 2.2.6 Coefficient of friction

The co-efficient of friction (C0F) of the test specimens were carried out using simple inclined plane method in which the specimen was allowed to freely slide down over the cast iron plane as shown in Figure 6. At the point of sliding, the plane was clamped and the angle of inclination (Ɵ) was measured after which the coefficient of friction (μ) was calculated using equation 2 (*Fono-Tamo et al. 2015*).

$$COF(\mu) = \tan\theta \tag{2}$$

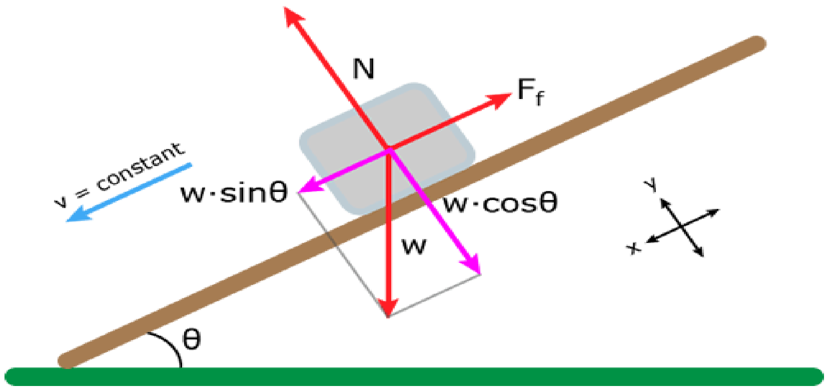


Figure 6: Free body diagram for the coefficient of friction test

# 3. Results And Discussion

## 3.1.1 Brinell hardness

In Table 2, it can be inferred that sample A has the best hardness property when compared to samples B and C under the same load condition of 3000 Kgf while hardness of sample B is slightly higher than that of sample C. The high brinell hardness number indicated by sample A could be as a result of its high tungsten content which stands at an average value of 9.83% when compared with the average value of 0.12% tungsten contents in sample B and 0.11% in sample C as indicated by the elemental composition results for each of the test specimen.

Table 2: Brinell Hardness Test Results

| S/N | Test Specimen | Test No | Load (Kgf) | Steel ball diameter, D (mm) | Indentation diameter,d (mm) | Mean Value,d (mm) | BHN |
|---|---|---|---|---|---|---|---|
| | | $SA_1$ | 3000 | 10 | 5.46 | | |
| **1** | A | $SA_2$ | 3000 | 10 | 5.44 | 5.46 | 117.15 |
| | | $SA_3$ | 3000 | 10 | 5.47 | | |
| | | $SB_1$ | 3000 | 10 | 5.70 | | |
| **2** | B | $SB_2$ | 3000 | 10 | 5.71 | 5.71 | 106.68 |
| | | $SB_3$ | 3000 | 10 | 5.71 | | |
| | | $SC_1$ | 3000 | 10 | 5.79 | | |
| **3** | C | $SC_2$ | 3000 | 10 | 5.78 | 5.78 | 103.22 |
| | | $SC_3$ | 3000 | 10 | 5.78 | | |

### *3.1.2. Izod impact strength*

In Table 3, the three test specimens tend to have an approximately the same value of impact strength when subjected to the same hammer drop at a maximum load of 150 J with the average Izod impact strength of samples A, B and C at 69.08 J, 69.17 J and 69.0 J respectively. This could be as a result

Table 3: Result of Izod Impact Test

| Test Specimen | Test No | Impact Strength(J) | Avg. Impact Strength(J) |
|---|---|---|---|
| | $SA_1$ | 69.50 | |
| A | $SA_2$ | 68.75 | 69.08 |
| | $SA_3$ | 69.00 | |
| | $SB_1$ | 69.00 | |
| B | $SB_2$ | 69.50 | 69.17 |

| | | | |
|---|---|---|---|
| | $SB_3$ | 69.50 | |
| C | $SC_1$ | 69.50 | 69.00 |
| | $SC_2$ | 68.50 | |
| | $SC_3$ | 69.00 | |

of their respective high carbon content with that of sample SA supplemented with the high iron content of 26.45%.

### 3.1.3 Tensile strength

Table 4: Results of Tensile Test

| Test Specimen | Test No | Yield Force (N) | Avg.Yield force (N) | Time to failure (Secs) | Avg. time to failure (Secs) | Elong. at Yield (mm) | Avg. elong. at yield(mm) |
|---|---|---|---|---|---|---|---|
| | $SA_1$ | 520.10 | | 9.43 | | 0.61 | |
| A | $SA_2$ | 520.90 | 520.87 | 9.42 | 9.44 | 0.62 | 0.61 |
| | $SA_3$ | 521.60 | | 9.48 | | 0.61 | |
| | $SB_1$ | 426.05 | | 6.80 | | 0.42 | |
| B | $SB_2$ | 429.90 | 426.51 | 6.82 | 6.76 | 0.42 | 0.42 |
| | $SB_3$ | 423.58 | | 6.67 | | 0.41 | |
| | $SC_1$ | 816.10 | | 10.82 | | 0.71 | |
| C | $SC_2$ | 813.22 | 815.03 | 10.72 | 10.79 | 0.72 | 0.72 |
| | $SC_3$ | 815.76 | | 10.83 | | 0.73 | |

Generally, was applied until samples A, B and C fractured at 520.87 N, 426.51 N and 815.03 N respectively. , it can be observed from Table 4 that the results indicated that the brake pad lining materials are highly brittle in nature, a condition that could be associated to the high carbon contents. Due to the high carbon content of sample B, it has the earliest average yield time of 8.76 seconds to failure and the lowest average yield force of 426.51 N when compared with the corresponding parameters for both samples A and C

(Table 4). Also, the average elongation of 0.42 m at yield point for sample B is the lowest of the three samples which is also as a result of the high carbon content while that of sample C is slightly higher than the corresponding values obtained for sample A.

The test result showed that sample C possesses the highest average yield force which stands at 815.03 N with samples A and B having the values of 520.87 N and 426.51 N, respectively. The average time to failure for sample A is 9.44 seconds, sample B recorded 6.76 seconds and sample C has 10.79 seconds. The average elongation at yield for samples A, B and C are 0.61 mm, 0.42 mm and 0.72 mm respectively.

### 3.1.4 Compressive strength

Table 5: Result of compressive test

| Test Specimen | Test No | Yield force (KN) | Avg. Yield force (KN) | Time to failure (Secs) | Avg. time to failure (Secs) | Def. At Yield (mm) | Avg. def. At yield (mm) |
|---|---|---|---|---|---|---|---|
| | $SA_1$ | 17.57 | | 15.99 | | 2.57 | |
| A | $SA_2$ | 17.65 | 17.68 | 16.21 | 16.09 | 2.61 | 2.62 |
| | $SA_3$ | 17.83 | | 16.06 | | 2.68 | |
| | $SB_1$ | 32.44 | | 13.37 | | 2.30 | |
| B | $SB_2$ | 32.45 | 32.46 | 13.52 | 13.41 | 2.18 | 2.24 |
| | $SB_3$ | 32.49 | | 13.33 | | 2.24 | |
| | $SC_1$ | 14.57 | | 7.77 | | 1.30 | |
| C | $SC_2$ | 14.56 | 14.59 | 7.66 | 7.73 | 1.29 | 1.29 |
| | $SC_3$ | 14.63 | | 7.75 | | 1.29 | |

Samples A, B and B yielded a load of 17.68 KN, 32.46 KN and 14.59 KN respectively. It can be observed from Table 5 that the test results obtained for each of the test specimen, shows sample A having average compressive strength value of 17.68 KN which is slightly higher than that of sample C at 14.59 KN despite the higher carbon content of sample C though it is lower than that of sample B. One of the factors that could be responsible for this variation is the higher tungsten percentage of 9.83% present in sample A when compared with that of sample C which is 11%.

The high average yield force indicated by sample B is as a result of its extremely high carbon content though its tungsten percentage is at 0.12%. Comparatively, sample A has the longest average time to failure of 16.04 s due to its higher tungsten and iron contents though with a higher deflection while sample C has the lowest average time of 7.73 seconds to failure and deflection of 1.29 mm.

### 3.1.5 Coefficient of friction

Table 6: Co-efficient of friction of the brake pads

| Test Specimen | Test No | Inclination Angle, Θ ($^o$) | Calc. Coefficient of Friction (μ) | Average COF (μ) |
|---|---|---|---|---|
| | $SA_1$ | 18.78 | 0.34 | |
| A | $SA_2$ | 18.78 | 0.34 | 0.34 |
| | $SA_3$ | 18.26 | 0.33 | |
| | $SB_1$ | 18.51 | 0.33 | |
| B | $SB_2$ | 17.99 | 0.32 | 0.32 |
| | $SB_3$ | 17.86 | 0.32 | |
| | $SC_1$ | 18.95 | 0.34 | |
| C | $SC_2$ | 17.55 | 0.32 | 0.33 |
| | $SC_3$ | 18.40 | 0.33 | |

The calculated coefficient of friction (Table 6) for the three test specimens A, B and C were virtually the same and they all fall within the range of coefficient of friction for brake pad lining materials as stipulated by NIS 323 (1997) which is between 0.3 and 0.4 as obtained by Fono-Tamo and Olufemi (2015).

## 4. Conclusions

The analysis of materials characteristics in brake pad with respect to Brinell hardness, tensile strength, compressive strength, impact strength and coefficient of friction for light weight vehicles has been carried out. From the results obtained, the following conclusions can be drawn, that:

(i) The brake pads have carbon as the reinforcing fibres and it is in larger percentage than other constituent elements used in the brake pads formulation.

(ii) The high carbon element present in these brake pads makes it highly brittle in nature consequently resulting in their respective low tensile strength capacity but with relatively suitable compressive strength capacity.

(III) The brake pads displayed a fair co-efficient of friction.

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