Mechanical properties of brake pad composite made from candlenut shell and coconut shell

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Abstract. Development of technology, driving a lot of demand for materials that are cheaper, durable, and environmentally friendly for various purposes, especially in the automotive field. The most important safety feature of any vehicle is its braking system. The ability of brakes is to provide safe and repeatable stopping, which is related to safety of automobiles and human. In this study, candlenut shells (CdNS) and coconut shells (CNS) are used as composite materials in the manufacture of brake linings. The presented research work investigates/explore the mechanical properties and physical of brake pad composites formed candlenuts shell (CdNS) and coconut shell (CNS) composite and wear performance of friction materials. The specific wear rate generally increases with the increase in applied load and sliding speed for all compositions.

Keywords: brake pad, candlenut shell, coconut shell, composite

1. Introduction

Environmental pollution is a serious concern because it has a direct bearing on human health and environmental sustainability. The use of automotive industry products that are easy and release particles into the atmosphere must be made with materials that are not objectionable and environmentally friendly. According to the results of health research, the use of brake linings made from asbestos material can produce dust which, if inhaled by humans, causes lung and brain cancer.\textsuperscript{[3, 4, 2]} The Central Bureau of Statistics (Indonesia) showed that motorcycle users in Indonesia reached 105 million, in 2016 and are expected to increase every year. Based on these data it can be estimated the level of use of brake lining with asbestos material in the long term which will certainly have a major impact on health. Other issues about the environment, especially organic waste are also the center of attention. Disposing of candlenut shells and coconut shells on the side of roads, rivers, and plantations can cause new problems in the surrounding environment such as garbage that has accumulated and is an eyesore. Based on this, organic waste handling solutions are needed by utilizing the potential of the candlenut shell and coconut shell, while increasing the economic value of the waste. The availability of these two organic wastes is quite a lot, so it can be used as a composite filler in the manufacture of non-asbestos brake pads.

Brake pads is a part of friction material component and are generally a composite with different combination of materials. The performance of friction material is strongly affected by selection of ingredients. Usually, commercial pads contain number of different constituents and its include binders, fibers, fillers, additives (abrasives and lubricants) and friction modifiers.\textsuperscript{[8,9]} Each of the constituents have different function in order to enhance the properties of the friction materials, and the selection of constituents usually based on trial and error. The advantages of using hazelnut shells and coconut shells as a composite material of brake lining is good friction properties and high thermal conductivity. Composite materials have many advantages, including lighter weight, higher strength and resistance,
corrosion resistance and wear resistance. And the skeletal material (reinforcement) that is often used is natural cellulose fiber and synthetic fiber. Pineapple leaf fiber was used in this research. Fiber works for increase the coefficient of friction and increase the mechanical strength of materials.

Many studies have examined the organic material for manufacturing brake pads. Ufoama P.A. [11], developed brake linings using composites made from coconut shells, palm seeds, and cashew shells. The wear test results of 0.025 mm / min - 0.06 mm / min showed an increase in the bonding strength of the brake lining 25-27 kg / cm². Rajmohan B. [9] developed brake linings using composites made from coconut shells, sugar cane, and snail shells. The wear test results of 3.55 x 10⁻⁶ mg / m - 4.13 x 10⁻⁶ mg / m are slightly lower than asbestos. From Literature reviewed so far, the use of combination candlenut shells (CdNS) and coconut shells (CNS) as raw material for brake pad production has not been reported. In this research, research will be made in making brake pads using a composite of candlenut shells and coconut shell as a base material. The effect of combination of this raw material on the wear rate, hardness, and morphology will be investigated.

2. Experimental
2.1. Materials
The materials used for the production of the brake pads were carefully selected and they include candlenut shells and coconut shells powder filler, polyurethane resin as binder materials, carbon as fibre reinforcement, iron sand (aluminum, copper and zinc) were used as abrasives. Important factors considered in selecting these materials include high coefficient of friction, low wear rate, good heat dissipation while retaining the mechanical strength, ability to dry, up as quickly as it passes through water. In critically analyzing the desired qualities of different forms of carbon, appropriate ratio was worked out for the basic raw materials.

2.2. Composite Preparation
The formulation design of the friction composite materials was carried out on the basis of four classes of frictional materials i.e fillers, binders, reinforcing fibers and property modifiers with fixed percentages by weight. The various compositions and the designations of composites are given in Table 1. The candlenut shell and coconut shell is preferred because of its uniformity in quality and chemical composition and better properties in respect of water absorption and wears resistance.

Table 1. Composition of brake pad samples

| No | Sample | Composition (wt.-%) |
|----|--------|-------------------|
|    |        | Candlenut Shell Powder | Coconut Shell Powder | Iron Sand | Pineapple leaf fiber | polyurethane resin | Carbon |
| 1  | S-01   | 35 | 25 | 5 | 5 | 25 | 5 |
| 2  | S-02   | 30 | 20 | 10 | 5 | 25 | 5 |
| 3  | S-03   | 25 | 15 | 15 | 10 | 25 | 10 |

The candlenut shell and coconut shell is made to powder by breaking them to small pieces and finely powdered using milling machine to get fine grains. The milling machine used for the crushing of different materials to different grit sizes as desired as shown in figure 1. Required amount of candlenut shell and coconut shell powder, iron sand powder and carbon is measured using physical balance machine with digital accuracy of even 1 mm. They were mixed together by manual blending for 90 min with the help of using mortar until a homogenous mixture was formed. After that this mixture is mix with polyurethane resin for 15 minute in the high speed making magnetic stirrer. Then mixed with pineapple leaf fibers that have been cut into sizes 2 cm. The above blended mixture was transferred into already treated metal backing plate placed in the mould. The mould of brake pad as shown in
figure 2. It was allowed to stay for 30 minutes upon which gelling started (the surface of the moulded samples was hot showing it is an exothermic reaction). At this moment a pressure of 15 kN/m² was applied using hydraulic press and left for 4 hours upon which full curing had taken place and heating with a temperature of 100 °C for 10 minutes. Then the samples are characterized for various physical and mechanical properties.

3. Results and Discussion

3.1. Water absorption

The Friction composite material affects the braking performance when absorbing water, it is necessary to test water absorption to determine the resistance of the brake pads to water. Water absorption test was carried out according to ASTM 570-98. The specimen cut into 30 mm × 30 mm × 10 mm and weighing done. The samples are kept dipping in water for 24 hours under room temperature. The percent of water absorbed was calculated from the following formula : [1,2,3,6,7]

\[
\text{% water absorption} = \frac{w_0 - w_1}{w_1}
\]  

(1)

where, \(w_0\) = weight of the sample before keeping in water, \\
\(w_1\) = weight of the samples after keeping in water

After soaking, the pads were brought out and cleaned of their surface moisture. They were weighed again, and their mass difference gave the mass of water absorbed and percentage absorption (over dry mass) where determined. Table 2 shows the percentage of water absorption by various sample.

| No | Sample | Dry (gr) | mass (gr) | Wet mass (gr) | Mass of water absorbed | % of water absorption |
|----|--------|----------|-----------|---------------|------------------------|----------------------|
| 1  | S-01   | 9.84     | 9.91      | 0.07          |                        | 0.00706              |
| 2  | S-02   | 10.04    | 10.09     | 0.05          |                        | 0.00496              |
| 3  | S-03   | 10.21    | 10.27     | 0.06          |                        | 0.00584              |
3.2 Hardness
This experimental work was done using the hardness tester on Rockwell B. The indentation process involves piercing or deforming the surface of the brake pad with a brinell ball of 3.175 mm in diameter with a minor load of 10 Kgf and a major load of 50 Kgf. The mean hardness value from 5 points was reported. The hardness test result is shown in Table 3.

| No | Sample | Point 1 (HR) | Point 2 (HR) | Point 3 (HR) | Point 4 (HR) | Point 5 (HR) | Average Hardness Test (HR) |
|----|--------|--------------|--------------|--------------|--------------|--------------|---------------------------|
| 1  | S-01   | 82           | 93           | 83           | 82           | 87           |                           |
| 2  | S-02   | 91           | 91           | 85           | 93           | 87           | 89                        |
| 3  | S-03   | 94           | 97           | 85           | 98           | 85           | 92                        |

The Hardness Rockwell test using a test scale between 40-100 HRK. The Higher the number on each scale means the harder the material being tested.

3.3 Wear Characterization
The Wear test used to calculate the loss of material from the surface of solid objects as a result of mechanical movements. Wear is generally analogous to the loss of material due to mechanical interactions of two surfaces that move sliding and loaded. This is a normal phenomenon that occurs if two surface objects rub against each other, then there will be wear or movement of matter that occurs between two objects rubbing together. The wear rate is calculated by the formula:

\[ N = \frac{w_0 - w_1}{A \cdot t} \]  

Where,  
- \( N \) = wear rate (g/mm² . sekon)  
- \( w_0 \) = initial weight of specimen before being tested (g)  
- \( w_1 \) = initial weight of specimen after being tested (g)  
- \( A \) = wider contact area (mm²)  
- \( t \) = contact wear time (s)

A pin-on-disc type friction used for the performance evaluation of wear characteristics of these friction composites under dry sliding condition at room temperature. The specimen is held stationary and the disc is rotated while a normal force is applied through a lever mechanism for 120 s. The surface of the disc was cleaned with ethanol before the start of every new experiment. Brake lining wear test data for the dry state is shown in the table 4. From the table, the rate is obtained the highest wear at S-01 sample with candlenut shell and coconut shell composition (35 wt.%, 25 wt. %).

| No | Sample | \( w_0 \) (g) | \( w_1 \) (g) | time (s) | \( A \) (mm²) | \( N \) (g/mm² .s) |
|----|--------|--------------|--------------|----------|--------------|----------------|
| 1  | S-01   | 62.24        | 62.01        | 120      | 36.27        | 5.28 x 10⁻⁵    |
| 2  | S-02   | 62.96        | 62.75        | 120      | 36.27        | 4.82 x 10⁻⁵    |
| 3  | S-03   | 64.57        | 64.41        | 120      | 36.27        | 3.67 x 10⁻⁵    |
3.4. SEM – EDS Characterization
Morphology of the composites was investigated by scanning electron microscope (SEM) and elemental analysis using Energy Dispersive Spectroscopy (EDS) JEOL brand JSM-6390A with System resolution analysis: 61 eV, ED geometry: Elevation = 350, Acceleration voltage: 20 kV. The results of SEM testing with each sample are shown in Figure 3.

From the results, it can be seen the distribution of the particles in the friction materials are different for each samples. Result of the elemental composition based on EDS analysis showed that the carbon is present in more or less equal amount in all formulations. High percentage of oxides can be found in S-01, which may weaken inter atomic bonding and reduce its strength. S-03 contains the least amount of oxygen. The dominant metal in the brake pads studied are iron (Fe), magnesium (Mg), carbon (C), and aluminium (Al), silicon (Si), kalium (K). One of the advantages of pineapple leaf fiber is that it may cannot be attacked by rust and increase the functionality as reinforcing fibers.
4. Conclusion
The test results obtained samples that have higher hardness have higher wear resistance. Therefore there is a correlation between hardness and wear. The results of hardness testing from several samples the specimen selected has the highest hardness at S-03 Sample with composition CdNS (25 wt.-%) : CNS (15 wt.-%) with value 92 HRK. The sample also has the lowest wear test with a value 3.67 x 10\(^{-5}\) g/mm\(^2\).s . Water absorption test shows that the sample S-03 has a low water absorption of 5.84 x 10\(^{-3}\) %. An overview on the available data shows that the average of many elements found on the samples were rather close. Overall testing results showed brake pads material delivers a brake pad with longer wear life, less dusting, higher stopping performance and safety. Produces a stronger pad with higher density and less resin for quieter, highly reliable braking performance and ensure quiet, clean braking performance.

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References
[1] Afiqah O et all. 2016 Elemental Composition Study of Commercial Brake Pads for Passenger Vehicle: A Case Study , Recent Advances in Mechanics and Mechanical Engineering p 29-34
[2] B H TAmbunan 2014 A Preliminary Study on Use of Candlenut Shell as a Renewable Source of Energy, Min Indonesia, Journal of Ocean, Mechanical and Aerospace Vol 9
[3] Darlington E. et all. 2015 Production of Eco-Friendly Brake Pad Using Raw Materials Sourced Locally In Nsukka, International Journal of Energy Technology nad Policy 5(11) : 47 - 54
[4] F.N. Onyeneke et all. 2014 Production of Motor Vehicle Brake Pad Using Local Materials (Perriwinkle and Coconut Shell), The International Journal of Engineering And Sciences (IJES) Vol. 03 Issue 09
[5] Ganguly A 2008 George R. Asbestos free friction composition for brake linings. Bull. Mater. Sci. 31(1): 19-22
[6] Kryachek V M 2004 Friction composites: traditions and new solutions (review).II-Composite materials. Powder Metallurgy and Metal Ceramics; 44(1-2): 5-16.
[7] Lemen R A 2004 Asbestos in Brakes: Exposure and Risk of Disease, American Journal of Industrial Medicine 45(3): 229-237
[8] Nidhi et all. 2006, Influence of amount and modification of resin on fade and recovery behavior of non-asbestos organic (NAO) friction materials, Tribology Letters 23(3): 215-222
[9] Rajmohan B 2017 Predict The trobological Properties on brake pad using coconut shell/ sugarcane/ sic powder hybrid composites, International Journal of Engineering and Innovative Technology (IJIEIT), Vol : 7 , Issue : 3
[10] Shiv Pal Singh 2015 Analysis of Brake-Pad Friction Material Formulation, International Journal of Advanced Engineering Research and Science (IJAERS), Vil. 2, Issue 8
[11] Ufuoma P.A. et all. 2017 The Development of Vehicle Brake Pad Using Local Materials - (Palm Kernel, Coconut And Cashew Shells As Base Materials) IOSR Journal of Engineering (IOSRJEN) Vol. 07 Issue 06.