Brake Pad Characteristics of Natural Fiber Composites from Coconut Fibre and Wood Powder

A Kholil1*, S T Dwiyati1, R Wirawan2 and Elvin M3
1Department of Mechanical Engineering, Engineering Faculty, Universitas Negeri Jakarta Campus A Jl. Rawamangun Muka, Jakarta, 13220, Indonesia.
2Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung Jl. Ganesha No.10 Bandung 40132, Indonesia.
e-mail: ahmadkholil@unj.ac.id

Abstract. The aim of the research is to develop brake pad of natural fibre composite from coconut fiber waste and wood powder. The characteristics of hardness, braking time and wear compared to the commercial brake pad had been studied. Test samples were produced by varying content of coconut fiber from 0 - 40% weight, wood powder content from 40% - 0 weight with 10% intervals. The percentage of polyester resin was made constant. The process of mixing ingredients started from filtering coconut fiber and wood powder using a filter with mesh size 40 μm. Then, the materials combined with certain composition in to a container and stirred until evenly mixed. The composite poured into the mold was design appropriate the motorcycle disc brake pad dimensions. The test results of natural fiber composites on brake pads showed different characteristic values on hardness, wear, and braking time tests.

1. Introduction
Brakes are a vital component of a vehicle that serve to help reduce speed, stop the vehicle and maintain the speed of the vehicle when passing on a downhill road [1]. Brakes are a very important regulator of motion and vehicle safety. Brakes that do not function properly can cause accidents because they crash into a vehicle that stops suddenly. The vehicle can't be controlled and finally crashes. Crash into a vehicle when passing a downhill road or falling into a ravine. This is due to the ability of the braking force which depends on the characteristics of the brake pad material. Brake pads are steel backing plates with friction material bound to the surface facing the brake disc [2]. The test equipment used was a brake pad test rig for determining the brake pad wear, brake disk temperature rise, and braking time under different braking conditions [3].

The brake pads generally consist of asbestos fibers embedded in polymeric matrix along with several other ingredients. The use of asbestos fiber is being avoided due to its carcinogenic nature. Therefore a new asbestos free friction material and brake pads has been developed [2].

Coconut fiber shows a good stiffness and is used in products such as floor mats, doormats, brushes, mattresses, coarse filling material, and upholstery. Coconut fiber, obtained from unripe coconut, is a natural fiber extracted from the husk of coconut. The coconut is steeped in hot seawater, and subsequently, the fibers are removed from the shell by combing and crushing, the same process as jute fiber. The individual fiber cells are narrow and hollow with thick walls made of cellulose, and each cell is about 1 mm long and 10–20 μm in diameter. The raw coconut fibers show length varying from 15 to 35 cm and diameter from 50 to 300 μm. When they are immature and then become hardened and yellowed because a layer of linen is deposited on their walls [4].
One coconut fruit produces 0.4 kg of husk containing 30% fiber. Coconut fiber consists of fiber and cork which connects one fiber with other fibers. Coconut fiber has the following physical properties: rough, colored, and stiff. The composition of the content of coconut husk includes hemicellulose (8.50%), cellulose (21.07%), lignin (29.23%), pectin (14.25%) and water (26.0%). Cellulose a compound like clay, insoluble in water and found in the cell walls of plant protectors [5]. Fiber an essential part of coir. Each coconut contains 525 grams of fiber (75% of coir) and 175 grams of cork (25% of coir) [6]. Figure 1a shows coconut fiber.

![Coconut Fiber](image1)

**Figure 1a. Coconut Fiber**

Figure 1b shows wood powder. An investigation was carried out on the use of sawdust to develop brake pads [9].

Palm kernel fibers (PKFs) were used to produce asbestos-free automobile brake pads [10]. Similarly, Development of asbestos-free brake pad using barges was investigated with a view to replace the use of asbestos whose dust is carcinogenic. The sieve bags were used in production of brake pad in a ratio of 70% bags - 30% resin using compression moulding [2]. A research was carried out on the use of banana peels [11] to replace asbestos in brake pad with phenolic resin (phenol formaldehyde) as a binder. The resin varied from 5 to 30% weight in an interval of 5% weight. This research therefore aimed to develop brake pad from agro waste material composite of coconut fiber and wood powder with a view to investigate the characteristics of hardness, braking time and wear as compared with the commercial brake pad.

2. Method

The materials for this test were taken from the waste. Coconut fiber was taken from the peel of coconut fruit and wood powder from sawdust. As a matrix, is used polyester resin with a fixed composition of 60% for all samples. This test aims to see the effect of changes in the composition of coconut fiber and wood powder so that the polyester resin matrix is fixed. The process of mixing ingredients started with filtering coconut fiber and wood powder using a mesh filter of size 40 μm to get fine material. Then mixing done in the container so that the mixing of coconut fiber and the wood powder was evenly mixed. Mixing ingredients according to Table 1, as follows:
Table 1. The composition of brake pad specimens

| Specimen | Coconut fiber (%) | Wood powder (%) | Polyester resin (%) |
|----------|-------------------|-----------------|--------------------|
| A        | 0                 | 40              | 60                 |
| B        | 10                | 30              | 60                 |
| C        | 20                | 20              | 60                 |
| D        | 30                | 10              | 60                 |
| E        | 40                | 0               | 60                 |

Test samples were produced by varying coconut fiber from 0 - 40% by weight, wood powder from 40% - 0 weight at 10% intervals and fixed percentage polyester resin. The formulation was mixed in a container, stirred to reach a homogeneous mixture and transferred to the mold plate with dimensions of 100 mm x 100 mm x 10 mm at a pressure of 2 tons for 60 minutes. The results were dried naturally by sunlight for three days. The material is cut partially with a size of 25 mm x 25 mm x 10 mm as a hardness testing sample for each sample. The remaining part of the canvass material, then cut with a saw following the size of the commercial brake pads. The lining material is glued then affixed to the bearing. The shape of the brake pads can be seen in Figure 2.

Figure 2. Test specimens

Hardness testing based on ASTM E 92 using the Vickers FV-300e test equipment. Each sample was tested three times and taken data-average. Testing hardness by giving a load of 10 kg.

The test rig was used to determine the performance of the brake pads produced with the different composition. The pads were tested for wear and braking time. A set of commercial brake pads was subjected to similar test for comparison. Figure 3 shows the schematic diagram of the brake pad test rig. It has a 1.5 kW motor with a provision for speed variation by using an inverter. The motor provides the energy required to set the wheel weights and the brake disc in angular motion. When a set of brake pad was fixed into the brake caliper assembly of the test rig, the system is switched and the drive shaft begins to rotate, then it allowed to attain a desired speed. Thereafter, a manual force was applied to the brake pedal that was similar to that of a motorcycle. Subsequently the braking time and brake pad material lost are recorded \[3\]. Tests carried out at speeds of 20 km/h at temperatures of 25°C, 50°C, 75°C, 100°C at disc brake. Every speed that has determined the test carry out three times so that three data obtained. Then the average value of the braking time obtained. The maximum load was given to the brake lever for 4 kg refers to the average grip of the human hand. This test to determine the effect of the composition of coconut fiber and wood powder at the time of braking with changes in temperature. This test was carried out on disc brake pads samples.

Wear testing was carried out using a test rig as shown in Figure 3. This test aims to obtain wear data after braking testing with a speed of 20 km/hr. Sample testing using disc brake pads. The test begins by
weighing the brake pads using a digital scale to measure the initial weight of the brake pad. After braking testing was carried outweighing again to obtain the mass of disc brake pads after testing. The mass difference between the brake pads after testing with the mass of the brake pad before testing becomes the mass reduction data of the disc brake pads. For this test the data were taken using Equation 1.

\[ w = m_0 - m_1 \]  

Figure 3. Schematic of brake pad test rig.

3. Results and Discussion
The result of the hardness values is shown in Figure 4, shows the variation of coconut fiber and wood powder composition to the hardness value. Specimen A with a composition of 0% coconut fiber and 40% wood powder has the highest hardness value of 59 VHN. The hardness decreases along with increasing of the composition coconut fiber or reduction of wood powder. The hardness value of the specimen with composition 40% coconut fiber and 0% wood powder is 44.3 VHN. The hardness value influenced by lower cellulose content in coconut fiber, it is about 21.09% [5] compared with wood powder which has 40.99% of cellulose [8]. The lower cellulose content in coconut fiber brings on the mechanical properties of coconut fiber is softer than wood powder. Consequently, specimen D and E with more coconut fiber composition have lower hardness compared to specimens A, B, and C which contain less coconut fiber composition. When compared with commercial brake pad hardness, the D and E specimen have, the closer violence to commercial brake pads violence.
Figure 4. Vickers hardness test result of specimens and commercial brake pad.

The braking time was obtained from the braking test measurement. Figure 5 shows the variation of material composition and temperature of braking to the breaking time. Specimen E results a value of 20°C in 0.2 seconds, 50°C at 0.25 seconds, 70°C at 0.31 seconds and 100°C at 0.37 seconds and specimen D with a value of 20°C at 0.31 seconds, 50°C at 0.34 seconds, 70°C at 0.42 seconds and 100°C at 0.51 seconds. Braking time of specimen D and E are closer to braking time of commercial breaks. In addition, the braking time of specimens D and E are faster than specimens A, B, and C. It is happening because specimen E contains 40% coconut fiber and specimen D contain 30% coconut fiber and 10% wood powder, have a rough surface so their braking ability are better than the others. This graph shows higher temperature, give slower braking time. It causes by polyester matrix used in the brake pad will be soft at higher temperature, thus reduced braking ability. In addition, at high temperatures the specimen can releases of molecules such as H₂O and other volatile molecules from decomposition process that can affect the braking ability of brake pads.
Figure 5. Disc braking time test result of specimens and commercial brake pad.

Figure 6. Wear test result of specimens and commercial brake pad.

Figure 6 shown relation between the wear of the brake pad to composition of wood powder and coconut fiber after braking test. The wear decreases as a composition of coconut fiber increasing. This graph as similar trend in the hardness value (see figure 5). The increasing of composition coconut fiber contributed to increasing hardness value which has affected to decrease wear of brake. From figure 6, it can be seen that specimens D and E have lower wear than specimen A, B, C and commercial brake pad, so that they have higher wear resistant than others. As the result, increasing coconut fiber content shown good wear resistance in braking.
4. Conclusions
The test results of natural fiber composites from coconut fiber and wood powder on brake pads showed different characteristic values on hardness, wear, and braking time tests. The hardness value decreased along with the decrease in the composition of wood powder containing cellulose. The braking time test shows that the decrease in wood powder content affects the decrease in braking time due to the changed hardness properties. The decrease in the hardness value in the test results is also followed by the wear value in the variation of the specimen for each test. Natural composite material brake pads with excess coconut fiber composition looks close to the test results of commercial brake pads. The results of this study prove that coconut fiber waste and wood powder can be used for motorcycle brake pads through appropriate composition comparisons. It is still too early to conclude which natural fiber composition is better, further testing is needed to obtain a suitable composition to meet the brake pads criteria.

Acknowledgment
Thanks to the Head of LPPM UNJ which has provided an opportunity to complete this research through PTUPT scheme 2019, as well as to the Director of Research and Community Service of the Ministry of Research Technology and Higher Education who has provided this research grant.

References
[1] T. S. Document. *Light Vehicle Brake Systems*, Hal. 135. 2015.
[2] S. B. H. V. S. Aigbodion., U. Akadike and J. O. A. F. Asuke. Development of Asbestos - Free Brake Pad Using Bagasse, *Tribol. Ind.*, vol. 32, pp. 12–18, 2010.
[3] A. O. A. Ibhadode and I. M. Dagwa. *Development of Asbestos-Free Friction Lining Material from Palm Kernel Shell*, vol. XXX, no. 2, pp. 166–173. 2008.
[4] Albrecht W., Fuchs H., and W. Kittelmann 2003 *non-woven: fabrics, raw materials, manufacture, applications, characteristics, test processing* (Weinheim: Wiley-Vch Verlag GmbH & Co. KCaA)
[5] S. Kalia et al. Cellulose-based bio- and nanocomposites: A review, *Int. J. Polym. SCI.*, 2011.
[6] E. Pelita, T. R. Hidayani, and A. Akbar. Analysis physical properties of composite polymer of coco fiber and polypropylene plastic waste with Maleic anhydride as crosslinking agent, *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 223, no. 1. 2017.
[7] O. L. Rominiyi, B. A. Adaramola, O. M. Ikumapayi, O. T. Oginni, and S. A. Akinola. Potential Utilization of Sawdust in Energy, Manufacturing and Agricultural Industry; Waste to Wealth, *World J. Eng. Technol.*, vol. 05, no. 03, pp. 526–539. 2017.
[8] R. C. Pettersen. *The Chemical Composition of Wood*, pp. 57–126. 1984.
[9] S. S. Lawal, K. C. Bala, and A. T. Alegbede. *Development and production of brake pad from sawdust composite*, no. 30, pp. 47–56. 2017.
[10] K. K. Ikpambese, D. T. Gundu, and L. T. Tuleun. Evaluation of palm kernel fibers (PKFs) for production of asbestos-free automotive brake pads, *J. KING SAUD Univ. - Eng. Sci.*, pp. 1–9. 2014.
[11] U. D. Idris, V. S. Aigbodion, I. J. Abubakar, and C. I. Nwoye. Eco-friendly asbestos free brake-pad: Using banana peels, *J. King Saud Univ. - Eng. Sci.*, vol. 27, no. 2, pp. 185–192. 2015.