Characteristics of wood powder, coconut fiber and green mussel shell composite for motorcycle centrifugal clutch pads

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Abstract. This research is motivated by the need for environmentally friendly motorcycle centrifugal clutch pads. Utilization composites of wood powder, coconut fiber, and green mussel shells for centrifugal clutch pads have not been much discussed in the research. Centrifugal clutch functions to transmit power from the engine to the drive train with a centrifugal force mechanism. This study aims to determine the characteristics of the hardness, wear, coefficient of friction, and microstructure of the composite. Composite material was made with three variations, namely specimen 1 consisting of 20% wood powder, 20% coconut fiber, 60% resin, and 0% shells. Specimen 2 made of 20% wood powder, 20% coconut fiber, 50% resin, and 10% shells. Specimen 3 is made from 20% wood powder, 20% coconut fiber, 40% resin, and 20% shells. All specimens were characterized by hardness testing according to ASTM E92 by the Vickers FV-300e. Each specimen was tested three times and the average data was taken. Wear resistance testing according to ASTM G99 by OGOSHI machine. Friction coefficient testing is based on the principle of friction in the inclined plane. While microstructure testing uses SEM by JEOL JSM-6510LA. The results show that the composition of wood powder, coconut fiber, and shell influenced the test results. Specimen 3 shows the highest value of hardness, wear, and coefficient of friction compared to others so that it can be used for the centrifugal clutch.

1. Introduction
Centrifugal clutch is a transmission part of the automatic motorcycle. This clutch works in a centrifugal force which pushes the clutch against the drum. Generally, the clutch uses asbestos material in which is harmful to human health and environment. Clutch transfer kinetic energy from a rotating crankshaft - coupled to a power source - to the transmission and wheels. The process of merging into a resource utilizing friction is friction material. Slippage produces heat generation, which is absorbed and eventually lost to the atmosphere by the clutch [1,2]. Non-asbestos based friction material is a multi-material system to achieve the desired mixture of performance properties [3]. Natural composite friction material for clutches and brakes can be classified in the following groups: fibers, binders, friction modifiers, and fillers. Friction material can be deformed, its job is to maintain a fairly high and stable coefficient of friction and good wear resistance during operation. They must have the ability to withstand the setback, impact and centrifugal force caused by heat during friction. Binders are the heart of a system that binds materials firmly so that they can perform the desired function in friction material. Fiber in
combination is added mainly for strength while a friction modifier is used to manipulate the desired friction range [4].

Functional fillers to enhance certain composite characteristic features such as resistance to fade and space filler to cut costs. Phenolic resins are always used as a binder in friction materials because of their low cost along with a good combination of mechanical properties such as high hardness, compressive strength, moderate thermal resistance, creep resistance, and excellent wetting ability with most materials. The choice of binder in non-asbestos friction material is still largely limited to phenolic and modified versions due to the unavailability of the right type of replacement resin along with reasonable costs. Limited information has been reported about the art of exploration of new resins for binder replacement currently used in recently published review articles with an emphasis on the serious need for research in this direction [4].

Composites are to produce better material compared to conventional materials. Composites fibers and particles are embedded in a matrix of other material. The composites prepared from the seashells are tested for various mechanical properties like toughness, tensile strength, impact strength, flexural strength [5]. In previous studies had researched the use of green shells for a mixture of brake pads [6]. Green mussel shell wastes consist of calcium carbonate and organic matrices, with the former accounting for 95-99% by weight. Being the richest source of biogenic CaCO₃, shell wastes are suitable to prepare high purity CaCO₃ powders [7]. The shell waste could be further processed to be the filler of polymer composites [8]. But there are limited studies in mussel shells used as filler in epoxy-based composites. The effects of shell particle content on the mechanical properties of the composites were investigated. It was shown that in all composites, the tensile strength and Young’s modulus values increase with the increase of mussel shell particles [7].

The wood powder is a waste produced by wood processing such as sawdust [9]. Wood powder is used because it has a high cellulose content [10,11]. An investigation was carried out on the use of sawdust to develop brake pads [11,12]. 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, a natural fiber extracted from the husk of the coconut. The coconut is steeped in hot seawater, and subsequently, the fiber is removed from the shell by combing and crushing, the same process as jute fiber [13]. This material is also used for brake lining material [11].

This study aims to determine the characteristics of hardness, wear, coefficient of friction, and microstructure of the composite. The researcher wants to find out how the characteristics of the test specimen with the variation of the green clamshell. So that the composition of wood powder and coconut fiber is fixed. The test results are examined against the possibility of use on motorcycle centrifugal clutch pads.

2. Methods
The material used in current study was an asbestos-free composite consisting of natural ingredients of coconut fiber (20% by weight) and sawdust (20% by weight), green shells are used as mixed specimens with vary (0%, 10%, 20% by weight), and phenol-formaldehyde resins used as binder given vary (60%, 50%, 40% by weight). Table 1 shows the contents of the test specimen.

| Specimen | Wood powder | Coconut fibre | Green mussel shell | Polyester resin |
|----------|-------------|--------------|--------------------|----------------|
| 1        | 20          | 20           | 0                  | 60             |
| 2        | 20          | 20           | 10                 | 50             |
| 3        | 20          | 20           | 20                 | 40             |

Table 1. The composition of specimens.

The natural ingredients of coconut fiber, sawdust, and green shells are prepared by cutting the stems into small pieces about 1 cm in length. Then the small rods are ground to get a fine rod to pass the 40 µm mesh filter. The formation of the test specimen is done by mixing all the ingredients into a container, stirring and then put into a mold. The mold has a volume of 161.4 cm³. The constituents are pressed...
under ambient temperature at a pressure of 2 tons for 30 minutes. Then heated in the oven with a temperature of 100°C for 30 minutes. After cooling the specimen is removed from the mold and the results can be seen in figure 1.

![Specimen Images]

Figure 1. Specimen of composites.

Methods of testing carried out by the needs of this type of testing. The type of testing carried out as follows: hardness testing according to ASTM E92 by Vickers FV-300e test equipment. Each specimen was tested at five points and the results were taken on average; wear testing according to ASTM G99 by the OGOSHI test machine; microstructure testing using SEM JEOL JSM-6510LA, and friction coefficient of each test specimen was determined with the aid of an inclined plane and a 90° wedge as illustrated in Figure 2. Each specimen was placed on the inclined plane with the wedge in place. The wedge position was varied to increase the inclination angle until the test sample was just about to slide down the plane. The resulting coefficient of static friction (μ) was calculated from Equation 1 [11,14,15]

\[ μ_s = \tan θ \]  

(1)

Where θ is an angle of repose at the instant of sliding.

![Coefficient of Static Friction Diagram]

Figure 2. Analysis of coefficient of static friction.

3. Results and discussion
The hardness test is used to determine the effect of composition variations of composite to the hardness value. The average test can be seen in figure 3.
Figure 3. Average hardness value of composites.

Specimen 1, containing 0% green mussel shell, has an average value of 31.56 VHN. Specimen 2 containing 10% of green mussel shells has an average value of 32.5 VHN. Specimen 3 which containing 20% green mussel shell has an average value of 33.36 VHN. These results indicate that increasing composition of green mussel shell make the hardness of composite will increase, so that specimen 3 with the highest composition of green mussel shell has the highest hardness value. Hardness of composites specimens 1, 2, and 3, it is seen in Figure 4. The hardness value influenced by green mussel shell content. The increasing component of the green mussel shell causes an increase in the value of the hardness. This is influenced by the CaCO$_3$ content in the green mussel shells [6,7].

Figure 4. Wear resistance.

In wear-testing result can be seen that Specimen 3 has higher wear than the others (Figure 4). The addition of the composition of the green mussel shell caused an increase in the wear of the specimen [16]. The nature of hard green shells does not have a good ability to bind to coconut fibers, wood powder, and resin. In contrast to the results of the coefficient of friction shows that the increasing composition of the green mussel shell causes an increase in the value of the coefficient of friction. Specimen 3 has a static friction coefficient of 0.4 higher than the other two specimens. This result can be seen in Figure 5. The addition of the composition of the green mussel shell causes an enhancement in the friction coefficient of the specimen [16].
Figure 5. Friction coefficient.

The difference results on each specimen in hardness, wear, and the coefficient of friction testing is influenced by differences in the composition of each specimen. The addition of the composition of the green shell causes an increase in the value of hardness, wear, and coefficient of friction. This increase is influenced by the bonding of the green shell powder on the composite. The fixed composition of coconut fiber and wood dust for all three specimens is equally influential for all three. so the characteristics of the test results are more influenced by the nature of the green shell. The microstructure of the three specimens can be seen in the SEM images that show the characteristic differences in each specimen as shown in figure 6. The composition of the green shell is more dominant in specimen 3 which can be seen in figure 6c.

Figure 6. SEM images of specimens.
The friction coefficient of conventional clutch pads of sliding material resin molding is usually in the range of 0.3 - 0.5 [3]. The value of the coefficient of friction test results showed that the three specimens have a coefficient of friction between 0.3 - 0.4. This shows that this clutch can be used as a material for a centrifugal clutch for an automatic motorcycle application. The wear value shows that there is an increase in wear with increasing green shell material. So that for optimal performance, specimen 3 is prefer characteristics as the clutch canvas material than others.

4. Conclusion
The composite of wood powder, coconut fiber, and green mussel shells on polyester resin have different characteristics with different compositions. The increasing component of the green shell shows an increase in the characteristics of hardness, wear, and friction coefficient. Increased wear and tear properties with the addition of a shell composition can make matters worse. So Specimen 3 shows the ideal value of hardness, wear, and friction coefficient used for centrifugal coupling, because it has characteristics that are close to coupling material.

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References
[1] Biczó R, Kalácska G, Szakál Z and Fledrich G 2016 Composite friction materials for brakes and clutches Sci. Bull. Ser. C Fascicle Mech. Tribol. Mach. Manuf. Technol. 30 21
[2] Jacko M G and Rhee S K 2000 Brake linings and clutch facings Kirk-Othmer Encycl. Chem. Technol.
[3] Bijwe J 1997 Composites as Friction Materials : Recent Developments in Non-Asbestos Fiber Reinforced Friction Materials-A Review Polym. Compos. 18
[4] Gurunath P V and Bijwe J 2007 Friction and wear studies on brake-pad materials based on newly developed resin Wear 263 1212–9
[5] Ramnath B V, Jeykrishnan J, Ramakrishnan G, Barath B and Ejoelavendhan E 2018 Sea Shells And Natural Fibres Composites: A Review Mater. Today Proc. 5 1846–51
[6] Kholill A, Dwiyati S T, Sugiharto A and Sugita I W 2019 Characteristics composite of wood powder, coconut fiber and green mussel shell for electric motorcycle brake pads Journal of Physics: Conference Series (IOP Publishing) pp 1–6
[7] Kocaman S, Ahmetli G, Cerit A, Yucel A and Gozukucuk M 2016 Characterization of Biocomposites Based on Mussel World Acad. Sci. Eng. Technol. Int. J. Mater. Metall. Eng. 10 438–41
[8] Abutu J, Lawal S A, Ndalian M B, Lafia-araga R A, Adediwe O and Choudhury I A 2018 Engineering Science and Technology , an International Journal Effects of process parameters on the properties of brake pad developed from seashell as reinforcement material using grey relational analysis Eng. Sci. Technol. an Int. J.
[9] Romimiyi O L, Adaramola B A, Ikumapayi O M, Oginni O T and Akinola S A 2017 Potential utilization of sawdust in energy, manufacturing and agricultural industry; waste to wealth World J. Eng. Technol. 5 526–39
[10] Pettersen R C 1984 The chemical composition of wood (ACS Publications)
[11] Kholil A, Dwiyati S T and Siregar J P 2020 Development Brake Pad From Composites Of Coconut Fiber , Wood Powder And Cow Bone For Electric Motorcycle Int. J. Sci. Technol. Res. 9 2938–42
[12] Lawal S S, Bala K C and Alegbede A T 2017 Development and production of brake pad from sawdust composite Leonardo J. Sci. 16 47–56
[13] Albrecht W, Fuchs H; and Kittelmann W 2003 Nonwoven: fabrics, raw materials, manufacture, applications, characteristics, test processing. (Wiley-Vch Verlag GmbH & Co. KCaA, Weinheim.)

[14] Adegbola J and Ohijegbon I O 2017 Development of Cow Bone Resin Composites as A Friction Material for Automobile Braking Systems

[15] Ibukun Olabisi. A 2016 Development and Assessment of Composite Brake Pad Using Pulverized Cocoa Beans Shells Filler Int. J. Mater. Sci. Appl. 5 66

[16] Dwiwedi S K, Srivastava A K and Chopkar M 2019 Fabrication and dry sliding wear study of Al6061 / mussel - shell particulate composites SN Appl. Sci.