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Research Paper

Natural Fiber Composites from Coconut Fiber, Wood Powder, and Shellfish Shell of Centrifugal Clutch Materials

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Abstract

Natural fiber materials are the sustainable sources used for future automotive elements, where the centrifugal clutch utilizes the frictional force on the clutch pads to transfer kinetic energy from the rotating crankshaft to the transmission and the wheels. These pads are produced from several natural composites, such as coconut fiber, as well as wood and shellfish powder, whose characteristics are being investigated for hardness, microstructure, and wear properties. Based on this study, performance analysis was carried out on the samples of composite centrifugal clutch applied to automatic motorcycles. As a comparison, subsequent analysis was conducted on the genuine clutch pad materials, where the results showed differences in the characteristics of each mixture composition of the natural fiber composites. This indicated that the addition of wood powder composition to the clutch pad increased the hardness and special wear values by an average of approximately 12.9 and 1.16%, respectively. Furthermore, the composite content was observed in the microstructure, as the maximum power and torque on the natural fiber materials were 10.7 hp and 17.17 N.m, respectively. The value was found to be closely similar to the genuine parts with maximum power and torque of 10.8 hp and 16.02 N.m, respectively.

Keywords: Natural fiber; Wood powder; Coconut fiber; Shellfish shell; Clutch pad

1. Introduction

Natural fibers are found to have great potentials for large-scale production, as substitutes for synthetic composite materials [1]. This is due to their easy decomposition towards being environmentally friendly materials [2-4]. The price of natural fibers is also cheaper than the synthetic types [1], although they have drawbacks based on non-uniform qualities. In addition, these materials are found to be resistant to heat [2]. The natural fibers with the potentials of being developed into composites are the coconut materials, which are durable, ductile, not easily broken, water-resistant, and uninhabited by termites. Therefore, this material is used as an alternative for composite development, due to being cheap and easy to obtain [5]. The addition of sawdust waste as a composite is also being utilized as a reinforcement material, which improves mechanical properties [6]. This composite is very easy to obtain and still being gradually processed towards broad utilization. The addition of shellfish shells is also potentially good as composite fillers [7]. This is because shellfish is one of the marine commodities with highly sufficient production. Besides the great potential observed in the manufacture of handicrafts and animal feed, the waste products also increase the concept of other beneficial values, such as being an alternative material in the production of composites [8].

The non-asbestos-based friction material is a multi-material system to achieve the desired performance properties of mixture elements [9].

This indicates the classification of natural composite clutch and brake friction materials in the following groups, namely fibers, binders, modifiers, and fillers. These classifications are arranged based on primary functions, as well as friction and wear controls [10]. The binder is often found at the heart of the system, tightly binding materials to perform the desired frictional functions. Fibers are also primarily added for strength, with modifiers being used to manipulate the desired friction range. Meanwhile, the functional fillers are used to enhance certain features of the composites [10], which helps to produce better materials compared to the conventional types. However, composite fibers and particles are embedded in the matrix of other materials, such as coconut texture, as well as wood and shellfish powder [11]. Wood powder is a waste generated from wood processing, such as sawdust, which is used due to having a high cellulose content [12]. Meanwhile, the shell composites are being tested for various mechanical properties, such as toughness, as well as tensile, impact, and flexural strengths, respectively [7]. The green mussel shell waste also contains calcium carbonate and organic matrix, with the previous weight reaching 95-99%. Being the richest source of biogenic $CaCO_3$, shell waste is suitable for preparing high purity calcium carbonate powders [13]. Subsequently, this waste is often processed into polymer composite fillers [14], although the study on oyster shells being used in epoxy-based materials is still limited. In previous studies, the characterization of clutch pads [15] was carried out, especially on the features of hardness, as well as friction, wear, and microstructure coefficients, respectively [15-17].

The centrifugal clutch on an automatic motorcycle also acts as a power-transfer transmission [17]. This is operated using the centrifugal force, which adjusts the clutch to the drum outer casing for connection. Also, it is often inserted into the drum, which contains several clutch shoes on the inner edge. The parts of the centrifugal clutch are subsequently shown in **Figure 1**. On the automatic motor, the centrifugal clutch is found to transfer kinetic energy from the rotating crankshaft to the transmission and the wheels [18, 19]. With a certain friction coefficient, the power merging process within the clutch uses the frictional force on the surface of the material [17, 20]. This force is often used to start the driven shaft from rest, gradually maintaining the proper speed without excessive slipping on the friction surface [15]. The clutch also serves to quickly and gently disconnect and connect the engine speed to the transmission. This indicates that the clutch should be resistant to friction and high rotation, to ensure no damages occur when transferring power from the engine speed to the transmission [19]. Some of the conditions that should be met in the clutch include, (1) Continue the engine speed to the transmission transfer, (2) Disconnect and connect the engine speed to the transmission, and (3) Gradually and evenly continuing the engine speed to the transmission transfer without bumping [17, 18].

This study aims to determine the characteristics of hardness, microstructure, wear and performance of centrifugal clutch pad samples, which are derived from natural fiber composites (wood and shell powders, as well as coconut fiber) and applied to automatic motorcycles. The results are to be compared with the genuine parts, to observe the difference in the obtained characteristics. This should provide a characteristic overview of the natural fiber composites, the ability of the clutch to transmit power and torque to the wheels, as well as suggestions for further future studies.

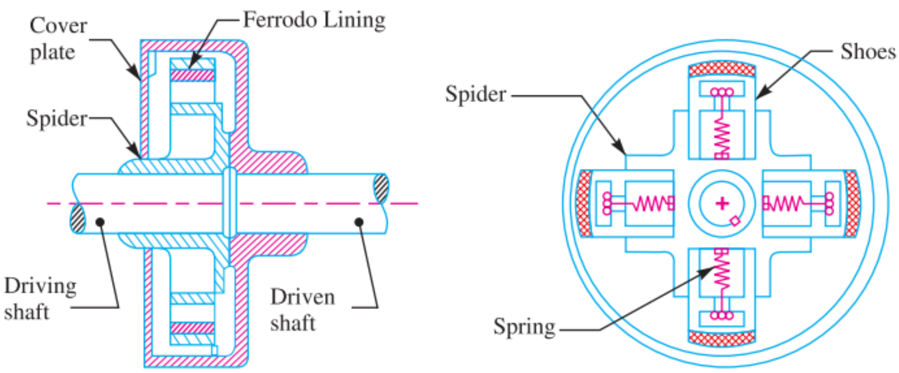

Figure 1. Centrifugal clutch [18]

2. Material and Method

The materials used in this study were wood and shell powders, coconut fiber, epoxy resin, and hardeners. The main materials of the natural fiber composites are shown in **Figure 2a-c**. These materials were obtained from the recycled production of wastes, as sources of eco-friendly automotive parts [4, 20].

The wood powder was produced from the sawdust waste of Sengon (*Albizia chinensis*) [15, 21], which was obtained from the furniture manufacturing site and separated from the coarse waste through filtering. This was mainly performed to obtain fine sawdust. The filtering process of this material was carried out twice using a sieve with 40 (400 microns) mesh size, to obtain fine sawdust powder **(Figure 2a)**.

The coconut fiber waste used in this study was obtained from the *Cocos nucifera* water drink sellers [15, 16]. This material was naturally dried under the hot sun and allowed to stand for one day, where dry fibers were subsequently grated and mashed using a grater. The process was carried out to separate the fibers from the coconut powder. Furthermore, the grated materials were filtered using a 40 (400 micron) mesh size sieve, to obtain a short and fine coconut fiber **(Figure 2b)**.

The shell powder used in this study was produced from the waste of the blood cockle shellfish (*Anadara granosa*) [7, 15], which was obtained from a seafood restaurant. These materials were thoroughly washed and dried in the sun for one day, where the dry shells were then mashed into powder. In addition, the filtering process used a 40 (400 micron) mesh size sieve to obtain a fine powdered material, as shown in **(Figure 2c)**.

Epoxy resin functioned as a matrix within the composite, to obtain a strong intermolecular attraction [10, 22]. These materials were widely sold in the market, leading to easy acquisition for use in this study. Also, it is often used as a binder in friction materials, due to cheapness and a good combination of mechanical properties, such as high hardness, compressive strength, moderate thermal and creep resistance, as well as excellent wettability [23]. In this study, the ratio of epoxy resin and hardener was 1:1.

Based on **Table 1**, the experimental procedure for sample composition was observed. This indicated that the composition of each ingredient was calculated according to the weight percentage. In addition, Specimen A contained a mixture of 0% wood powder, 40% coconut fiber, 10% shell grain, and 50% polyester resin. The process of producing specimens was carried out by mixing all the ingredients into a container, accompanied by stirring and placing them into a mould, which was pressed with a hydraulic jack at ambient temperature and two tons of pressure for 30 mins. This was subsequently heated in an oven at 130°C for 60 mins. After cooling, the sample was removed from the mould, with a similar procedure being conducted for specimens B-E. The shape of the mould [15] is illustrated in **Figure 3**, where it was observed to be made of welded steel plates and assembled with bolts, to have a volume of 161.5 cm^3.

Figure 2. Powder materials for composite mixtures: (a) wood, (b) coconut fiber, (c) shellfish shell

Table 1. The composition of specimens

Specimen	Composition (% weight)			
	Wood powder	Coconut fiber	Shellfish shell powder	Polyester resin
A	0	40	10	50
B	10	30	10	50
C	20	20	10	50
D	30	10	10	50
E	40	0	10	50

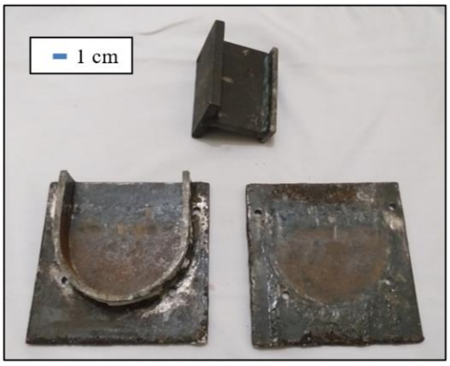

Figure 3. Mold for made specimen

Based on this study, the composite produced from the mould was cut into several parts, where the curved dimension was prepared for the clutch lining. This was performed with a corresponding size to the genuine part of the clutch pad shoe. Moreover, the section was cut according to the thickness of the clutch pad at 4 mm, with the cutting preparation process shown in **Figure 4a-c**. Subsequently, the pad composites were attached to the clutch shoe with metal glue (dextone), with the results shown in **Figure 4d**. This is equally applied to each specimen as shown in **Figure 5**. Additionally, the specimens were used for testing the clutch performance [17].

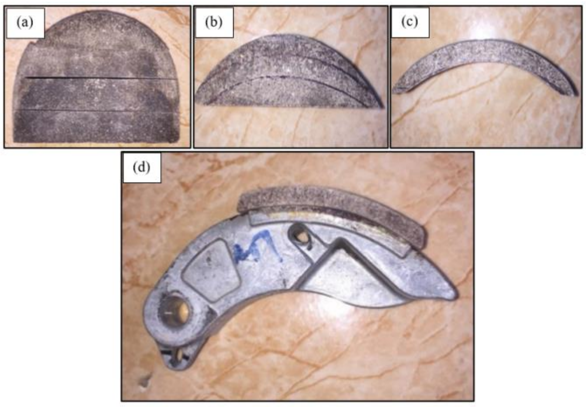

Figure 4. Preparation of specimen: (a-c) cutting process, (d) clutch shoe.

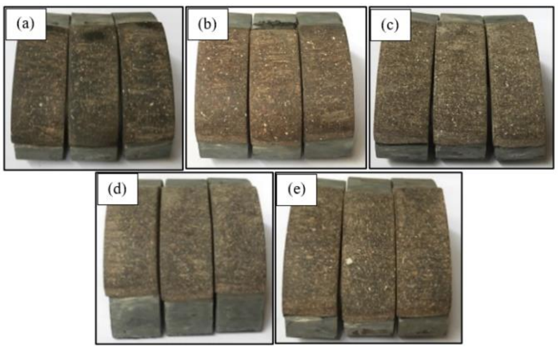

Figure 5. Specimen for performance test: (A-E).

The sliced rod-shaped section of the moulded composite (**Figure 4a)** was separated and used to analyze the specimens' hardness, as well as the friction, wear, and microstructure coefficients, respectively. From left to right, the analyzed specimens (A-E) are shown in **Figure 6**.

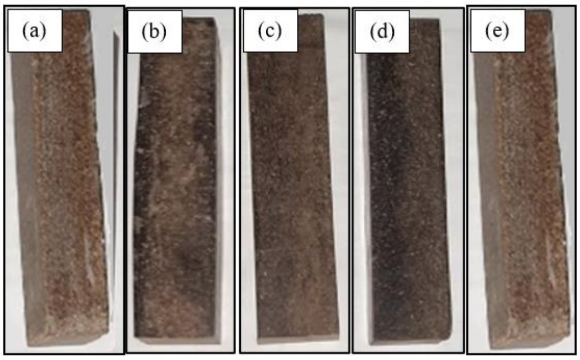

Figure 6. Specimens A-E for testing: hardness, coefficient of friction, wear and microstructure

Based on this study, the testing method included several types of analysis as follows:

- According to ISO 6507 [24, 25], the hardness test was conducted using HV (Vickers' hardness) method. This analysis was subsequently carried out using the FV 300e microhardness Vickers tester [15]. Based on this study, the specimens were cut to a length, width, and height of 20, 20, and 10 mm, respectively. These materials were levelled using 400 and 1000 sandpapers until the surfaces were well-smoothened. As a comparison, the genuine clutch pad material was also tested. Also, all specimens were carried out using a similar method. Based on the hardness test, 5 points were averagely obtained between the distance of 3-5 mm. In addition, the load in each test was 3 kg at 10 s.
- Using the scanning electron microscope (SEM) and energy-dispersive X-ray (EDAX) with JEOL JSM-6510LA [15, 26], the microstructure analysis was conducted. This indicated that the microstructure of the composite was observed from the SEM image, while the number of elements was obtained from the EDAX. In this analysis, the magnification of the specimen was 100x, with a length, width, and height of 10 mm each. Furthermore, all specimens were carried out using a similar method. Based on the genuine clutch pad material, the microstructure was also comparatively analyzed.

- Using a wear-test machine ogoshi method [15, 26], the wear analysis was conducted based on determining the specimen's resistance to abrasion [20]. Using an ogoshi high-speed universal testing machine (Type OAT-U), this analysis was conducted with 3.16 kg, 100 m, and 1.97 m/s of load, glide distance, and velocity, respectively. The results were based on the scratches obtained from the revolving disc tracking, which were subsequently measured to determine the ogoshi wear value. The procedure was averagely conducted thrice before data collection, where the specimens were cut to a length, width, and height of 20, 20, and 10 mm, respectively. As a comparison, the genuine clutch pad material was also tested for wear, with all specimens carried out using a similar method.
- Using the chassis dyno test [17, 27, 28], the motorcycle performance analysis was conducted. This required each test specimen to be mounted on an automatic motorcycle with a 150 cc engine capacity, to determine the level of performance. The test was directly carried out on a motorcycle, where the rear tyre was in contact with the dyno roller. Using a safety rope, this analytical process was conducted by tying the front wheel, as well as the left and right bodies of the motorcycle, to maintain balance at the opening of the throttle. Furthermore, the motorcycle tyres should be in good and prime conditions at standard pressure, to ensure no slip occurs during movement (between the tyres and the roller dyno). As a comparison, genuine clutch pads were also tested, with all specimens subsequently analyzed using a similar method.

3. Result and Discussion

Based on the hardness value, the variational effect in the composite material of wood and shell powders, as well as coconut fiber, is shown in **Figure 7**. The addition of wood powder in the clutch pad increased the hardness value by an average of 12.5% This led to an increase in the cellulose content, which improved the hardness value [2, 15]. These values were found to subsequently increase when improving the crystallite size [29]. In **Figure 7**, the hardness of the genuine pad was 23.2 HV, indicating that the test specimen close to this value had 40% wood powder at 21.4 HV. Furthermore, the dominance of the wood powder in this composite mixture caused an increase in the value of hardness, which was lower than the genuine pad. This was due to the absence of metal content in the composite material, as shown in **Table 2** based on the EDAX results. The hardness value of the lowest composite sample also had 0% wood powder, due to the dominance of coconut fiber in the mixture. This indicated that the increase in the volume of wood powder affected the hardness value. In addition, the shell material of only 10% had a hardness value for all test specimens [15].

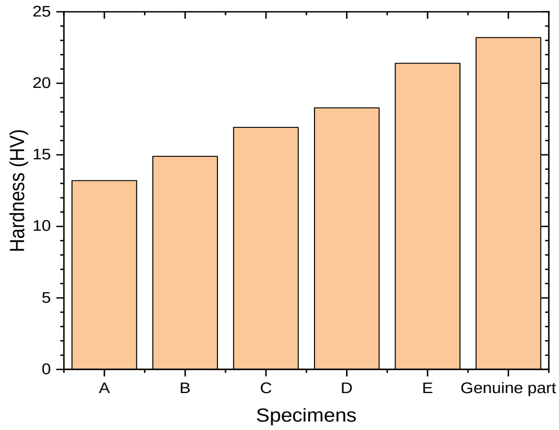

Figure 7. Vickers hardness value of each specimen

Based on **Figure 8**, the SEM image microstructure characteristics of each specimen was observed [25]. This indicated different images with several elemental contents. For each specimen, the elements contained in the energy dispersive X-ray (EDX) test is shown in **Table 2**. This showed that the elemental content of the genuine clutch pad contained metal materials, indicating that the hardness value was higher when compared to natural composites. Based on the factors of raw materials [2, 21], the number of different elements in these composites was due to the uniformity of the natural parts. According to Table 2, the amount of carbon for each specimen of the natural composites was higher than the samples of the genuine parts. This signified that the elemental calcium was lower than the genuine part specimen, due to the 10% shells not being evenly distributed throughout the samples. Therefore, the calcium contents of Specimens D and E were lower when compared to the other samples [13, 14].

Table 2. The elements contained in the EDX results of each specimen

Specimen	Percentage of element (%)								
	C	O	Ca	Si	Cl	K	Ti	S	Mg
Genuine part	41	35	17.05	0.43	0.5	1.40	3.60	0.55	0.19
Specimen A	78	19	1.43	0.18	0.46	0.29	-	-	-
Specimen B	75	21	1.68	0.45	0.33	-	-	-	-
Specimen C	68	27	1.43	1.28	0.29	0.24	-	-	-
Specimen D	76	22.49	0.79	0.31	0.25	0.17	-	-	-
Specimen E	72	23	0.26	0.45	-	-	-	-	-

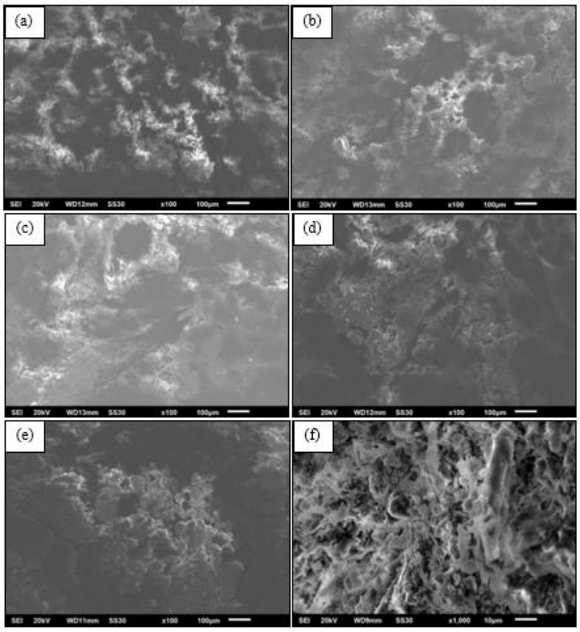

Figure 8. Scanning electron microscopy (SEM) images of (a-e) specimen A-E, (f) genuine part

Based on the wear test, the specific value for each sample was different, ranging between 1.081×10^{-5}-1.032×10^{-5} mm²/kg. The variational effect in the composition of wood sawdust, coconut fiber, and shell powder on the specific wear value is subsequently shown in **Figure 9**.

Based on **Figure 9**, the specific wear [20] increased and decreased with the rise in the compositions of the wood powder and coconut fibers, respectively [10, 15]. The graph also showed that Specimen A (without wood powder) had a specific wear value of 1.081×10^{-5} mm²/kg, which was lower than the other samples. Moreover, each 10% addition of sawdust led to an increase of 1.16% specific wear. According to Ojo et al. [30], the addition of sawdust had an impact on the wear value and degradability of the brake pad. This implied that a high amount of sawdust had an increased degree of degradability/wear [1, 3, 30]. The results also showed that the specific wear value of the genuine clutch pad was 0.448×10^{-5} mm²/kg. This indicated that the material had the best wear value than other specimens, due to its lower SWV (specific wear value) [11]. Also, the low hardness value of the composite material had less ability to withstand the wear rate on the surface of the specimen. This was due to the higher wear value of the material [26]. In addition, the 10% shell content was unable to provide wear resistance to the composite clutch pad. However, several studies showed that seashell friction elements had good mechanical and tribological properties [1, 3, 14]. For further future studies, the shell content variations should be investigated.

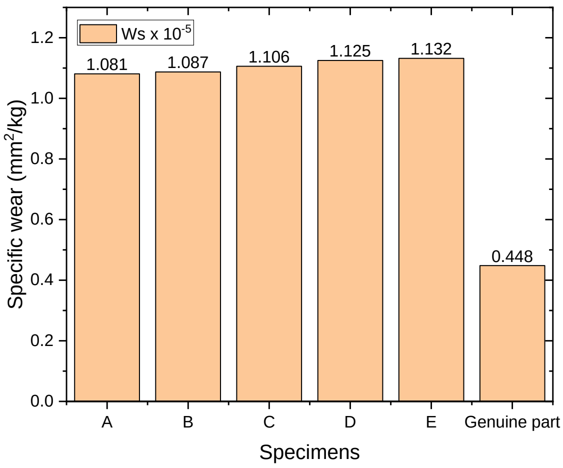

Figure 9. Specific wear of specimens.

Using a chassis dyno test on each sample, the power and torque values obtained from the analysis of motorcycle performance were different for the rotation changes. This led to the variational determination in the power and torque values between the genuine clutch pad and each specimen, as shown in **Figure 10**. The highest torque value for all test specimens was 4500 rpm. This showed that the torque value of genuine parts was lower than that of other specimens. Moreover, the TV (torque value) produced by the genuine clutch at 4500 rpm was 12.56 N.m. Meanwhile, at 4500 rpm, the highest torque value produced by the specimens with 30% wood powder, as well as 10% coconut fiber and shells, was 16.18 N.m. This was because the composition of wood powder was more dominant, causing the hardness value to increase and provide a greater gripping force on the drum [24]. Also, the addition of more dominant wood powder increased the hardness of the composite [15]. The results also exposed that trend of increasing torque began from low rotation to the engine speed at approximately 4500 rpm. This was subsequently decreased with increasing rotation, as applied to all specimens including the genuine parts [27]. The results revealed that this composite material had several advantages at low and high rotations. However, these results were bad based on the wear analysis. This was due to the high average wear level when compared to the genuine clutch pad.

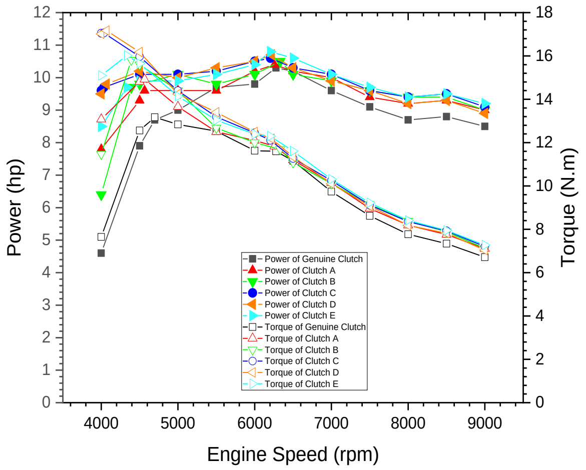

Figure 10. Power and torque at each engine speed from chassis dyno test results

Based on this study, the power transmitted by the clutch to the wheels showed the highest value at 6200 rpm. This suggested that the power increased with the ability of the clutch, to absorb transmittable energy from the engine to the drive [19]. Also, the highest power increase reached 6200 rpm and slightly decreased in the next round. According to **Figure 10**, the power transmitted to the drive had a higher value when compared to the genuine clutch energy. In addition to the low rpm, this composite material had a higher power increase, compared to the genuine clutch. This was reportedly sufficient to increase good acceleration at low rpm. However, further studies are still needed to determine the actual performance on the highway, with traffic conditions and motorcycle loads also being highly considered. In addition, other parameters such as flame resistance, coefficient of friction, as well as oil and water absorption also need to be tested as reported by Adetunji [31] to get a more comprehensive specification.

4. Conclusion

Based on the analytical results, this study succeeded in analyzing and reporting the characteristics of hardness, microstructure, wear, and the centrifugal clutch pad performances on the natural composite samples obtained from wood powder, coconut fiber, and shell grain. These results are as follows,

a. The addition of wood powder composition to the clutch pad increased the hardness value. This led to an increase in the cellulose content, subsequently increasing the hardness value. However, the HV (hardness value) of this composite material was still below that of the genuine clutch.
b. The microstructure characteristics of the test specimens showed differences with several elemental contents, which did not contain metal elements. This signified that the hardness value was lower when compared to genuine clutch pad materials.
c. The wear value increased with the increasing composition of the wood powder. This revealed that the specimens with 0 and 40% wood powder had the smallest and greatest wear values. However, when compared to the WV (wear value) of the genuine clutch pad material, it was still higher. This indicated that the composite material was more worn than the genuine parts.
d. The power and torque values for the composite materials were higher. However, these values varied from low to high rotations for each sample of the genuine parts. At low rpm, the composite material had a large torque, which was quite good for acceleration. Meanwhile, the high wear value indicated that improvements were still required for further studies.
e. The results provided knowledge on the potential sources of natural fiber composites, based on the utilization in one of the frictional elements within the automotive components. Therefore, improving the quality and reliability of this composite is very necessary, based on the utilization in highway conditions.

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Author's Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study, with responsibility claimed for the data analysis, interpretation, and discussion of the results. The authors read and approved the final manuscript.

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Competing interests

The authors declare no competing interest.

Additional information

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