HARDNESS AND FRICTIONAL RESISTIVITY OF COCOPEAT (*COCOS NUCIFERA)*-POLYMER COMPOSITE

S. A. Bahari[1], M. A. Kassim[1], C. M. S. Said[1], M. I. Misnon[1], Z. Mohamed[2]

[1]Faculty of Applied Sciences and [2]Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia.
E-mail address: sbinbah@gwdg.de

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Abstract

Two particle sizes of cocopeat were prepared in Cocopeat (Cocos nucifera)-polymer composite manufacturing; one screened using 80 mesh seive and the other at 100 mesh seive respectively. The particle ratio used was 10 and 30%; hot moulded and cured together with other ingredients such as phenol formaldehyde, magnesium oxide and barium sulfate acting as the reinforcing agent. Hardness and frictional tests were conducted in accordance to the Malaysian Standard MS 474 and SAE J661, respectively. Test results obviously show that respective samples containing 30% CHP with 80 mesh give highest hardness resistance value, implying that the small particle size of CHP fill-up the voids in the composite. However, in contrast, the friction test value of composite containing 30% CHP with 100 mesh is lower as compared to the samples containing 10% CHP.

1 Introduction

Cocos nucifera husk particle (CHP) or cocopeat has a great potential to be used as a filler in the polymer composite manufacturing for abrasive material in motorcycle brake pad application. Abrasive material is also classified as composite product due to the variety of raw materials combination. As part of automotive, brake materials have additional requirements such as friction [1]. Friction brakes are used to decelerate a vehicle by transforming the kinetic energy of the vehicles to heat through friction and dissipating that heat to the surroundings [1]. In the manufacturing point of view, the typical materials in brake pads compositions are abrasives, friction modifiers, fillers, reinforcements and binder materials [2]. According to Solomon and Berhan [3], the mean friction coefficient of friction materials made from resin and other metallic ingredients was in the range of 0.316 to 0.374. The product exhibits good thermal stability from 200 to 800 ^{0}C [3]. However, Blau [1] stated that asbestos has had a historical role as a typical brake additive. In 1986, The Environmental Protection Agency has announced a proposed ban on asbestos as a filler material, due to the human health issues [1].

The potential utilization of natural materials such as agricultural waste to replace synthetic filler in the brake pad manufacturing has to be studied [4]. Coconut husk particle seems to be one of the potential agricultural crops to be used in motorcycle brake pad industries. Coconut husks, residues generated during coconut processing, are available in abundant quantities in many parts of the tropic but are often treated as waste material [5]. According to Tan *et al* [6], about 151,000 ha of land in Malaysia was being used for coconut plantation in the year 2001. It was estimated that 5280 kg of dry husks were become available per hectare per year [6]. At present, coconut husks are used as fuel for coconut processing, as a domestic fuel and as a source of fiber for rope and mats [6]. Since coconut husk is abundant and cheap, the manufacturing cost of brake pads can generally be reduced. According to Suzuki *et al* [7], coconut coir dust has the highest percentage of lignin (42%) compared to other agricultural waste materials. Van Dam *et al* [8] in their study stated that lignin content in coconut husk has influenced the good thermal stability. The percentages of coconut husk material in the polymer composite for abrasive application can also be varied. Mutlu [9] has concluded that the brake pad filled with 20% rice husk gave the best result in term of frictional behaviour. The present study has confined to this range of variation for natural particle percentages. The main objective of this study is to determine the hardness and frictional resistivity of Cocopeat (*Cocos Nucifera)*-polymer composite for abrasive material in motorcycle brake pad application. The hardness and frictional resistivity of Cocopeat (*Cocos Nucifera)*-polymer composite was also compared with commercial automotive brake pad.

2 Materials and testing methods

The main raw materials in this study were binder resin, friction producer/modifier, abrasive material, reinforcement and filler. The cocopeat husk was obtained from the local wet market and transported to Bio-Composite Laboratory, UiTM Shah Alam, Selangor. The husks with fewer impurities were selected as raw material and cut into smaller pieces using manual cutter knife. The small pieces of husk were cut into particle using hammer milling machine. The cocopeat husk particle (CHP) was screened into two different types of particle size, such as 80-mesh (large particle) and 100-mesh (small particle) sizes. The particle was dried to 1 - 2% moisture content (MC) in oven dryer for a week. The composite production was conducted at Advanced Materials Research Centre (AMREC), Standard and Industrial Research Institute of Malaysia (SIRIM), Kulim, Kedah. The dried CHP was mixed together with phenolic resin (phenol formaldehyde) as binder, copper, graphite and brass as friction producer/modifier, magnesium oxide as abrasive material, steel and barium sulfate as reinforcement. Shaking machine was used in the 30-minutes mixing process. Two different types of percentage for CHP were used in this study, such as 10 and 30%. Table 1 shows the raw material percentage for Cocopeat (*Cocos Nucifera)*-polymer composite for abrasive material in motorcycle brake pad application.

Raw Material	Raw Material Percentage (%)	
	Type 1	Type 2
CHP	10	30
Phenolic Resin	20	20
Copper	5	5
Magnesium Oxide	3	3
Graphite	7	7
Brass	2.5	2.5
Steel	10	10
Barium Sulphate	42.5	22.5
Total	100	100

Note: Type 1= Automotive Brake Pad Composed with 10% CHP
Type 2= Automotive Brake Pad Composed with 30% CHP

Table 1. Raw Material Percentage for Cocopeat (*Cocos Nucifera)*-polymer composite for abrasive material in motorcycle brake pad application

After mixing process, the blended powder was pre-pressed for 30 seconds using 4-tonne load hydraulic press. After pre-pressing process, the samples were pressed for 10 minutes using hot pressing machine with 50 tonne pressure at 150 C. The samples were then baked for 4 hours in a 150 C post-curing process using furnace. The purpose of this process was to ensure that the phenolic resin is completely cured. Figure 1 shows the Cocopeat (*Cocos nucifera)*-polymer composite sample. The composite was finally cut and trimmed into specific size for hardness and friction resistance tests. Samples from the commercial automotive brake pad were also prepared and cut in a same dimension with Cocopeat (*Cocos nucifera)*-polymer composite sample for properties' comparison purpose.

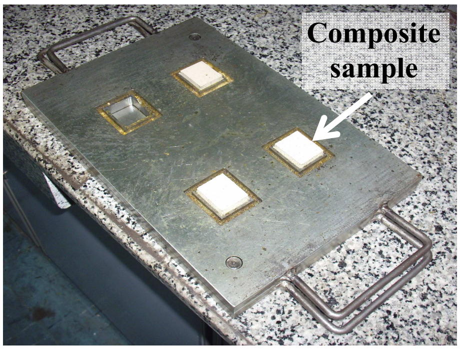
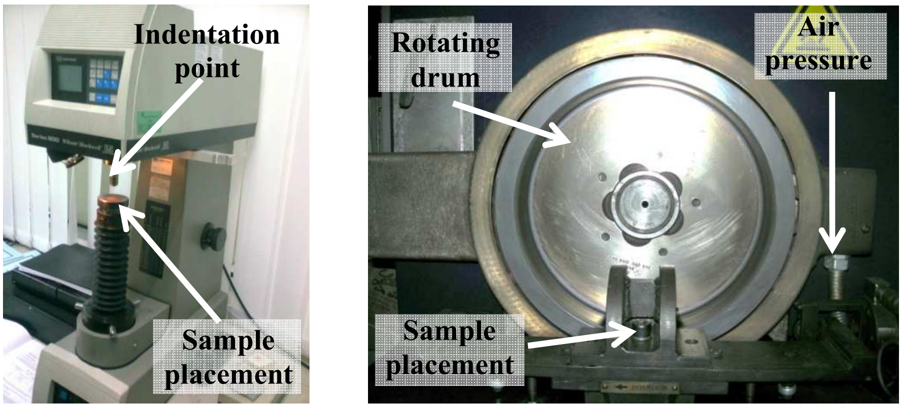


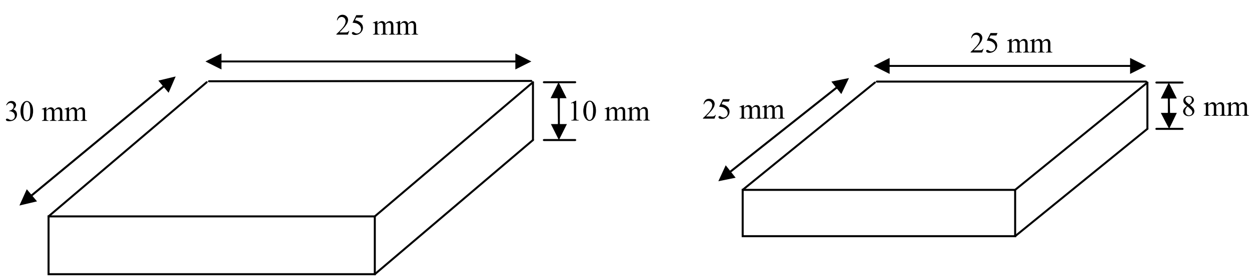
Figure 1. Cocopeat (*Cocos nucifera)*-polymer composite sample

Figure 2 shows the equipment used to determine the hardness and friction resistance in this study, while Figure 3 shows the dimension of hardness and friction test sample. Hardness resistance test was conducted at Mechanical Engineering Laboratory, Faculty of Mechanical Engineering, UiTM, Shah Alam, Selangor. Malaysian Standard MS 474 [10] was referred as a standard in hardness testing. Rockwell hardness testing machine (HRR Scale) was used to record the hardness resistance data. Five (5) points of hardness measurement were distributed uniformly over the surface of sample. All samples were positioned perpendicular to the indentation mounting spindle, and the load was applied on the sample surface. Friction resistance test was conducted according to SAE J661 [11]. Chase machine was used to record the friction coefficient (μ) for composite samples. The samples were pressed using an applied load of 667 N against a rotating brake drum with a speed of 417 rpm. Dyno-Lite portable digital microscope (215x magnification) was used to observe the typical surface failure of these samples after friction test.



(a) (b)

Figure 2. Equipment used to determine the hardness and friction resistance in this study, (a) hardness machine, (b) Chase machine



(a) (b)

Figure 3. Dimension of hardness and friction test sample: (a) hardness, (b) friction

3 Results

Figure 4 shows the hardness resistance value of Cocopeat (*Cocos nucifera)*-polymer composite mixed with different sizes and percentages of CHP. For 10% CHP, hardness resistance of samples with 100 mesh (91.22 HRR) was higher than 80 mesh (87.70 HRR). For 30%, hardness resistance of samples with 80 mesh (103.50 HRR) was higher than 100 mesh (99.71 HRR). In 10% composition, smaller CHP size has increased the capability to resist continuous load. In contrast, for 30% composition, smaller CHP size has reduced the hardness resistivity. It shows that smaller particle size performed better as a filler material within lower composition of CHP in the sample. For 80 mesh, hardness resistance of samples with 30% composition (103.50 HRR) was higher than 10% composition (87.70 HRR). For 100 mesh, hardness resistance of samples with 30% coconut husk dust (99.71 HRR) was also higher than 10% composition (91.22 HRR). In general, hardness resistance of samples with 30% composition was higher than 10%. The high amount of CHP that filled the empty spaces has increased hardness value. In this way, it was possible to obtain composite materials with properties quite similar to the already known synthetic filler with their superior properties. It made the composite more compact. According to Mutlu [9], more organic material in the mix causes increased only in wear rates, not in hardness.

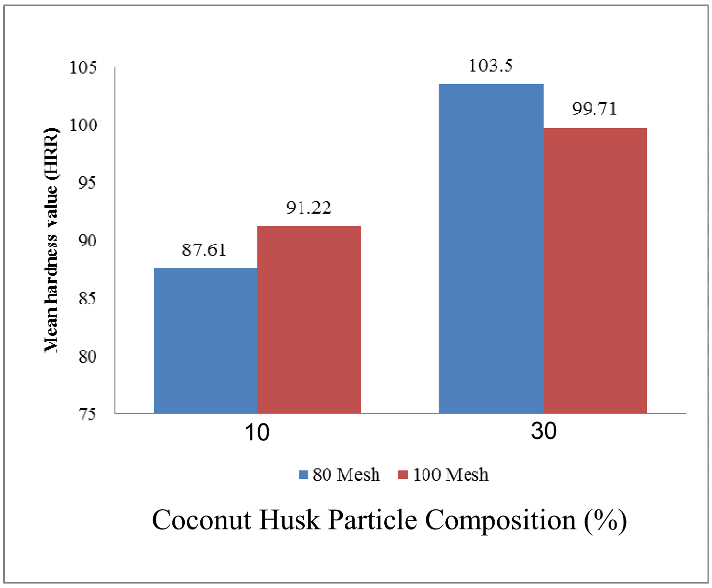


Figure 4. Mean hardness resistance value of Cocopeat (*Cocos nucifera)*-polymer composite mixed with different sizes and percentages of CHP

Figure 5 shows the mean μ values of Cocopeat (*Cocos nucifera)*-polymer composite mixed with different sizes and percentages of CHP. For 10% CHP composition, the mean μ values of automotive brake pad mixed with 100-mesh of coconut husk particle were higher (0.348) than 80-mesh (0.313). In contrast, for 30%, the mean μ values of automotive brake pad mixed with 80-mesh of coconut husk particle were higher (0.290) than 100-mesh (0.282). This was due to the fine particle size in 30% mixture tends to increase the contact area of the automotive brake pad, thus reduces the friction resistance. For 80-mesh, the mean μ values of automotive brake pad mixed with 10% coconut husk particle were higher (0.313) than 30% (0.290). For 100-mesh, the mean μ values of automotive brake pad mixed with 10% coconut husk particle were also higher (0.348) than 30% (0.282). Figure 6 shows the typical surface of worn samples after friction test. It is seen that CHP is distributed uniformly in the metallic and resin matrix; regardless of the particle size. Samples with 10 % CHP contain more metallic material compared to samples with 30 % CHP. The friction behaviour is greatly dependent upon metallic matrix contents. High percentage of CHP as an organic filler creates a weakness to the samples in term of frictional properties.

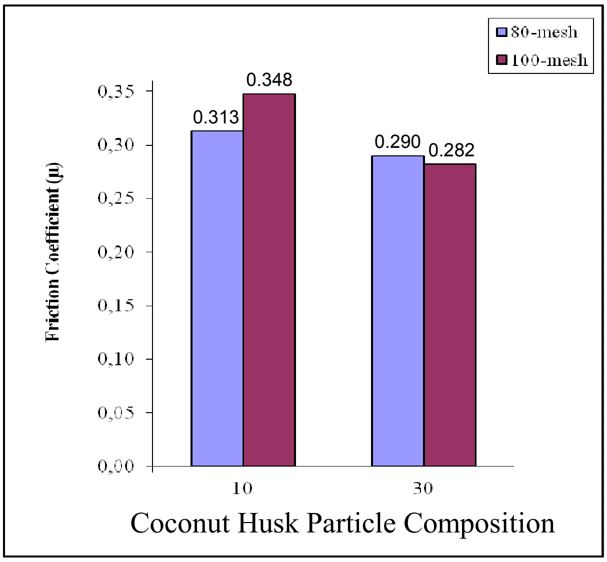


Figure 5. The mean μ values of Cocopeat (*Cocos nucifera)*-polymer composite mixed with different sizes and percentages of CHP

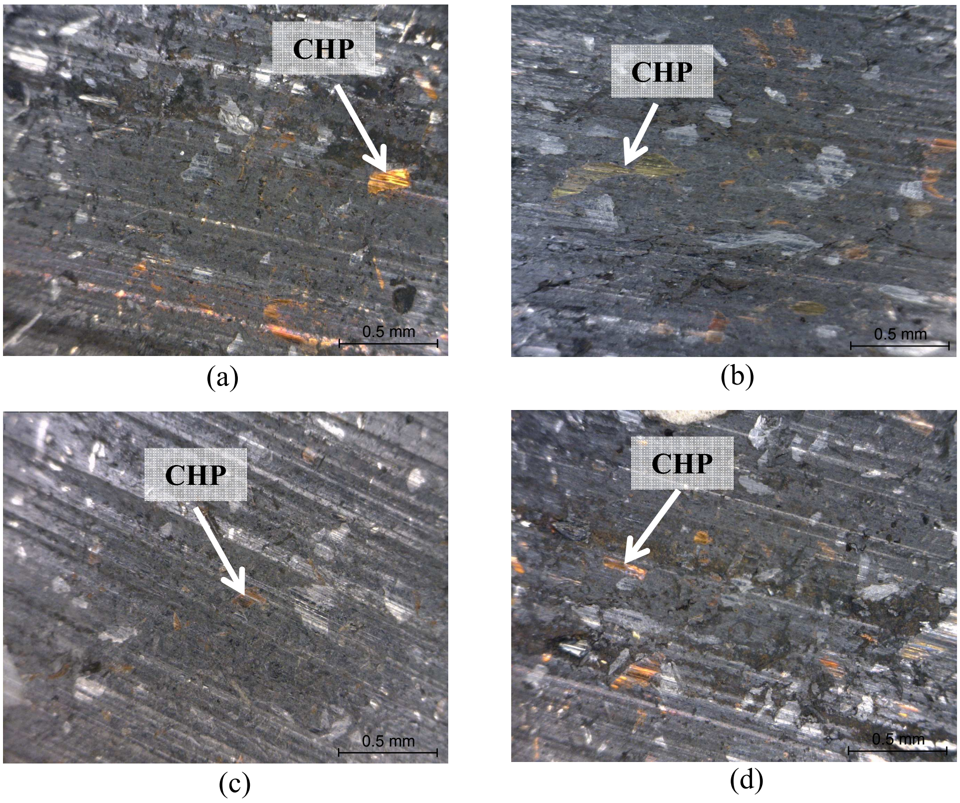


Figure 6. Typical Surface of Worn Samples after friction test (215 x magnification): (a) Sample with 80-mesh, 10 % CHP, (b) Sample with 80-mesh, 30 % CHP, (c) Sample with 100-mesh, 10 % CHP, (d) Sample with 100-mesh, 30 % CHP

Table 2 shows the general comparison of HRR and μ between Cocopeat (*Cocos nucifera)*-polymer composite and commercial automotive brake pad. The hardness resistance of composite from CHP was better than commercial automotive brake pad. 30% composition of CHP was the best in term of hardness. It shows that the high percentage of CHP showed better result in hardness value. The mean μ values of Cocopeat (*Cocos nucifera)*-polymer composite were generally lower than commercial automotive brake pad. Being a metallic material, the commercial brake pad has full capability to operate at high temperature condition and has stable friction coefficient [12]. However, the mean μ values of Cocopeat (*Cocos nucifera)*-polymer composite have passed the minimum requirement stated in SAE J661 [11], which is 0.25.

Types of composite		**Mean hardness (HRR)**	**Mean Friction Coefficient, μ**
Cocopeat (*Cocos nucifera)*-polymer composite	80M 10%	87.70	0.313
	80M 30%	103.50	0.290
	100M 10%	91.22	0.348
	100M 30%	99.71	0.282
Commercial automotive brake pad		86.52	0.413

Note: M – Mesh

Table 2. General Comparison of HRR and μ between Cocopeat (*Cocos nucifera)*-polymer composite and commercial automotive brake pad

4 Conclusions

Cocopeat (*Cocos nucifera)*-polymer composite from a combination of 80-mesh (large particle size) and 30% particle (high particle percentage) exhibited the highest value of hardness resistance. Composite from a combination of 100-mesh (small particle size) and 10% particle (low particle percentage) exhibited the highest friction resistance. Coconut husk which contains high lignin has influenced the low friction resistance of brake pad for 30% particle.

Hardness resistance of Cocopeat (*Cocos nucifera)*-polymer composite was generally better than commercial automotive brake pad. 30% composition of CHP was the best in term of hardness. It shows that the high percentage of CHP showed better result in hardness value. Based on this comparison, the formulation of brake pad with CHP is possible to be produced. However, friction resistance of Cocopeat (*Cocos nucifera)*-polymer composite was generally lower than commercial automotive brake pad. The presence of CHP in the brake pad composition has led to the low friction resistance. However, friction resistance of Cocopeat (*Cocos nucifera)*-polymer composite have passed the minimum requirements stated in the standards.

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