Characteristics composite of wood powder, coconut fiber and green mussel shell for electric motorcycle brake pads

A Kholil*, S T Dwiyati, A Sugiharto and I W Sugita

Department of Mechanical Engineering Education, Engineering Faculty, Universitas Negeri Jakarta, Kampus A Jl. Rawamangun Muka, Jakarta, 13220, Indonesia.

*ahmadkholil@unj.ac.id

Abstract. The brake pads mostly consist of asbestos fiber with polymeric matrix and other ingredients. The use of asbestos fiber is been avoided due to its carcinogenic nature. The main purpose of this study was to determine characteristics of the composite made from wood powder, coconut fiber, and green mussel shell that will be used for electric motorcycle brake pads. Composites were made with three variations. Specimen A consisted of 30% wood powder, 10% coconut fiber, 10% green mussel shell and 50% polyester resin. Specimen B consisted of 20% wood powder, 20% coconut fiber, 10% green mussel shell and 50% polyester resin. Specimen C consists of 10% wood powder, 30% coconut fiber, 10% green mussel shell and 50% polyester resin. All specimens were characterized by hardness testing according to ASTM E 92 by Vickers FV-300e test equipment. Each specimen was tested three times and taken data-average. Decomposition testing used TGA NETZSCH TG 209F3. The results of the characterization were compared with commercial brake pads. Specimens with the closest characteristics to the commercial brakes were shown by specimens A with 33.1 VHN and decomposition temperature 90 °C.

1. Introduction

Brake pads are steel backing plates with friction material bound to the surface facing the brake disc. The brake pads generally consist of asbestos fiber embedded in polymeric matrix along with several other ingredients. The use of asbestos fiber is been avoided due to its carcinogenic nature [1].

Composites are produced with a combination of a matrix material generally a metal, a fibre and filler materials glued together using a resin. The main aim of composites is to produce better material compared to conventional materials. In nowadays, composites fibers and particles are embedded in matrix of other material. With growing global awareness, utilization of natural fibres in composites has been steadily increasing. Similarly, researches are being done in sea shell’s abilities as possible fillers in modern world. The physic and mechanical properties such as hardness, toughness, water absorbent qualities, tensile strength are found to be satisfied by different sea shells. The composites prepared from the sea shells are tested for various mechanical properties like toughness, tensile strength, impact strength, flexural strength [2].

The wood powder a waste produced by wood processing such as sawdust [3]. Sawdust possesses characteristics similar to wood but due to the fact that it is in particles shape so that some structural properties have been altered. Moreover, in general, the wood powder has chemical compositions such as holocellulose (70.52%), cellulose (40.99%), lignin (27.88%), pentosan (16.89%), ash (1.38%), and water (5.64%) [4]. An investigation was carried out on the use of sawdust to develop brake pads [5].
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 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. 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 fiber shows length varying from 15 to 35 cm and diameter from 50 to 300 μm. When mature, they become hardened and yellowed because a layer of lignin is deposited on their walls [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 shell 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 aim of this study was to prepare composites reinforced with various composition of wood powder, coconut fiber and green mussel shell using fixed polyester resin and to investigate its hardness and thermal properties.

2. Materials and methods
Waste wood powder, coconut fiber, green shells used for composite materials. As a matrix, it is used polyester resin with a fixed composition of 50% for specimens. The materials of wood powder, coconut fiber, and green mussels shells are mashed, then filtered using a 40 μm mesh filter to obtain a smooth material. Then mixing done in the container so that the mixing of the powder materials was evenly mixed. Mixing ingredients according to Table 1, as follows:

| No. | Specimen | Composition (% weight) |
|-----|----------|------------------------|
|     |          | Wood powder | Coconut fibre | Green mussel shell | Polyester resin |
| 1   | A        | 30          | 10           | 10                  | 50             |
| 2   | B        | 20          | 20           | 10                  | 50             |
| 3   | C        | 10          | 30           | 10                  | 50             |

Every specimen was mixed in a container, stirred to reach a homogeneous mixture and transferred to the mold plate at a pressure of 2 tons for 60 minutes. The results were dried naturally.

![Specimen A](image1.png) ![Specimen B](image2.png) ![Specimen C](image3.png)

Figure 1. Specimen of composites.
Specimens were tested for hardness testing based on ASTM E 92 used the Vickers FV-300e test equipment. Specimens from commercial brake material were also tested for hardness with the same tools and methods. Each specimen was tested three times and taken data-average. Decomposition testing used TGA NETZSCH TG 209F3.

3. Result and discussion

Hardness testing was carried out to determine the effect of variations in composition of wood powder, coconut fiber and green mussel shells on brake pad hardness. The results of the hardness test can be seen in Figure 2.

![Figure 2. Hardness of composites.](image)

![Figure 3. Decomposition of specimen A.](image)

Specimen A, containing 30% wood powder, has a hardness value of 33.1 VHN. Specimen B containing 20% of wood powder has a hardness value of 32.3 VHN. Specimen C which containing 10% wood powder has a hardness value of 30.6 VHN. These results indicate that increasing composition of wood powder make the hardness of composite brake linings will increase, so that specimen A with the highest composition of wood powder has the highest hardness value. Of the three specimens A, B and C, it is seen in Figure 2. Specimen A has hardness value that is closest to commercial brake lining that is equal to 40 VHN. The hardness value influenced by lower cellulose content in coconut fiber, it is about 21.09%
compared with wood powder which has 40.99% of cellulose [4]. The lower cellulose content in coconut fiber bring on the mechanical properties of coconut fiber is softer than wood powder.

TGA testing was carried out at room temperature to 400°C. The TGA test results for specimen A are shown in Figure 3. The graph shows that specimen A begins to decompose at 90 °C. While Specimens B and C began to decompose at lower temperatures, namely 70 °C and 55 °C (Figure 4 and 5). Decomposition that occurs in specimen A at 90 °C is a decomposition of water molecules absorbed from wood powder and coconut powder. Wood powder and coconut powder are natural hygroscopic fibers. Specimens B and C containing more coconut powder and besides that they also containing more volatile matter. This volatile matter has a lower decomposition temperature, so that specimens B and C with more coconut fiber cannot stand on high temperatures.

![Figure 4. Decomposition of specimen B.](image)

![Figure 5. Decomposition of specimen C.](image)

TGA diagram of three specimens show mass reduction at temperature 320°C which was observed with a sharp decrease in Figure 3. According to the literature the decomposition temperature of polyester is 357 °C, so that the mass reduction at 320 °C – 400 °C is a polyester decomposition process. The amount
of mass reduction is 50% according to the polyester content in the brake lining composites which is made the same in all three specimens.

The composition of the shellfish which is only 10% also contributes to hardness value and heat resistance [2,7]. Shellfish containing CaCO₃ compound, will be decomposed at 720°C [10], so in the end of TGA process at temperature 400°C, residual mass still contain 10% CaCO₃ and other residual like carbon. Residual mass at 400°C for specimen A is 19.00%, Specimen B 32.80%, Specimen C 39.30%, but since the application temperature of brake pad is below temperature 100°C, so the results concerned with thermal resistant at temperature about 100°C.

Of the three specimens, specimen A began to decompose at a higher temperature than the other two specimens. In other words, specimen A had greater thermal resistance. The thermal resistance of specimen A was higher than the working temperature of the motorcycle brake lining at a temperature of 100°C, so that specimen A could be used for electric motorcycle brake pads application.

4. Conclusions
The composite of wood powder, coconut fiber, and green mussel shells on polyester resin have different characteristics with different compositions. The results of this study show that the specimen A having hardness value closest to commercial brake lining hardness number of ~40 VHN. Specimen A had also begins to decompose at a higher temperature than others so it has a greater thermal resistance. Moreover, thermal resistance of specimen A is higher than the working temperature of electric motorbike brake pads thus it suitable for electric motorcycle brake pad application.

Acknowledgement
This work is supported by Engineering Faculty Universitas Negeri Jakarta. The authors would like to express the gratitude and sincere appreciation to the Director of Research and Community Service of the Ministry of Research Technology and High Education who has provided this research grant.

References
[1] S B H V S Aigbodion, U Akadike and J O A F Asuke 2010 Development of Asbestos - Free Brake Pad Using Bagasse, Tribol. Ind., 32, pp. 12–18.
[2] B V Ramnath, J Jeykrishnan, G Ramakrishnan and B Barath 2018 Sea Shells And Natural Fibres Composites : A Review, Mater. Today Proc., 5(1), pp. 1846–1851.
[3] O L Rominiyi, B A Adaramola, O M Ikumapayi, O T Oginni and S A Akinola 2017 Potential Utilization of Sawdust in Energy, Manufacturing and Agricultural Industry; Waste to Wealth, World J. Eng. Technol., 05(03), pp. 526–539.
[4] R C Pettersen 1984 The Chemical Composition of Wood, Chem. Solid Wood, pp. 57–126.
[5] S S Lawal, K C Bala and A T Alegbede 2017 Development and production of brake pad from sawdust composite, Leonardo J. Sci., 30, pp. 47–56.
[6] W Albrecht, H Fuchs and W Kittelmann 2003 Nonwoven: fabrics, raw materials, manufacture, applications, characteristics, test processing. Wiley-Vch Verlag GmbH & Co. KCaA, Weinheim.
[7] S Kocaman, G Ahmetli, A Cerit, A Yucel and M Gozukucuk 2016 Characterization of Bio-composites Based on Mussel, World Acad. Sci. Eng. Technol. Int. J. Mater. Metall. Eng., 10(4), pp. 438–441.
[8] J Abutt, S A Lawal, M B Ndaliman, R A Lafia-araga, O Adedipe and I A Choudhury 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] S Kalia et al. 2011 Cellulose-based bio- and nanocomposites: A review, Int. J. Polym. Sci.
[10] S Abdolmohammadi, S Siyamak, N A Ibrahim, W Zin and W Yunus 2012 Enhancement of Mechanical and Thermal Properties of Polycaprolactone / Chitosan Blend by Calcium Carbonate Nanoparticles, Int. J. Mol. Sci., pp. 4508–4522.