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EFFECT OF BAMBOO WEIGHT FACTION ON MECHANICAL PROPERTIES IN NON-ASBESTOS COMPOSITE OF MOTORCYCLE BRAKE PAD

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Abstract. This study aims to determine the mechanical properties of the use of brake pads based on composite materials from bamboo fiber, and to evaluate the effect of replacement of brake pad material made from asbestos with natural materials to avoid the impacts of asbestosis substances, such as cancer. The method used several stages: weighing, mixing, inserting materials in molding, compacting, and sintering. The stages were carried out in three types of composites: Composite 1 (40% of bamboo fiber, 30% of MgO, and 30% of epoxy resin), composite 2 (50% of bamboo fiber, 25% of MgO, and 25% of epoxy resin), and composite 3 (60% of bamboo fiber, 20% of MgO, and 20% of epoxy resin). Tests for mechanical properties were carried out using a standard analysis, such as wear rate using ASTM D3702-94 standard, hardness test using ASTM D 785-03 type R, heat resistance using 2300 testing temperature, and composite brake lifetime analysis. The results showed that the composition of bamboo brought great influences on the mechanical properties. The best specimen had a wear rate of $0.9612.10^{-8}$ g/mm^2.s, hardness of 91.8 HRR, and heat resistance at 280°C with a duration of 810 days. It is expected that the use of composite brake pads made from bamboo fiber can replace brake pads made from asbestos, which is healthier and safer to use.

Keywords: asbestosis, bamboo fiber, composite material, brake pad

1. Introduction

Brake Pad is one of the important components in motorized vehicles on the highway. The development of two-wheeled motorized vehicles is currently increasing rapidly in line with the economic growth in the community. Along with rapid growth, problems often occur in vehicles such as brakes that can cause cancer due to the existence of asbestos dust during breaking [1-4].

The quality of brake lining is determined by several factors, including the composition of the material, the type of material, and the hardness of the material. Brake lining made from asbestos braking ability will decrease at a temperature of 200°C, and above that temperature will cause brake failure [5]. One alternative that is being developed for use on motorbikes is changing the composition of brake pads, based on the green composite concept.

Green composite criterion is material that has one or two components (matrix and reinforcing fibers) as a biological based component [6,7]. This component can be: (a) Natural reinforcing fibers with synthetic polymeric matrix (polyolefins polyester, epoxy, vinylester, phenolics), (b) Natural polymer matrix (Polylactic Acid / PLA,

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PolyhydroxyAlkanoat / PHA) reinforced with natural fibers (jute, ramie, bamboo), and (c) Natural polymer matrix reinforced with synthetic fibers (E-glass or carbon fiber).

Composites consist of a combination of two or more materials on the macroscopic scale. In practical condition, the composite consists of a main material (matrix), and one type of component as a reinforcement to increase the strength and stiffness of the matrix. The reinforcement component is usually in the form of fibers. Composite materials have advantages such as lighter weight, stronger, higher durability, corrosion resistance, and having good wear resistance [8].

Natural lignin-based reinforcing fibers (such as bamboo, flax, palm fiber, and coconut) have been shown to contribute better to green composite strength [9]. The reasons for choosing natural fibers for green composites are:

(1) Adverse effects of application of natural fibers are smaller than synthetic fibers,

(2) Applications of natural fibers can reduce the use of synthetic matrices because for the same performance composites need more natural fibers than synthetic fibers,

(3) On automotive applications, lower natural fiber density can support increased fuel oil efficiency,

(4) CO_2 emissions from combustion of green composites are smaller than synthetic composites.

Bamboo fiber is used as an existing substitute material because it is economical and light [10]. The latest development found the advantages of bamboo fiber green composites, in which the vibration reduction capacity of the product was better than glass fiber synthetic polymer composites [11]. Researches on green composite reinforced bamboo fiber and epoxy matrix have been carried out, even applied for bulletproof vests. Bamboo fiber is quite efficient, lightweight, and more economical for bulletproof applications compared to aramid fiber [12]. Modification of bamboo fiber for epoxy composites proves an increase in tensile strength and significant elongation in resulting new composite [13].

Here, this study aims to determine the mechanical properties of the use of brake pads based on composite materials from bamboo fiber. This bamboo was used for replacing brake pad material made from asbestos with natural materials to avoid the effects of asbestosis substances, such as cancer. As a model of bamboo, *dendrocalamus asper* was used. *Dendrocalamus asper* is one type of bamboo that has a large stem size and is included in the tribe of grasses. The researches begun with making a mixture of ingredients. The formula consists of several constituent materials, such as binder (epoxy resin), fiber material (bamboo fiber), and filler material (MgO). Then, the process of mixing the ingredients until the production of brake pads is made with several variations of the addition of bamboo fiber.

The making of brake pads is determined based on a predetermined reference, such as the value of mechanical properties must be based on the value of the safety standard [14]:

(1) For the value of violence according to safety standards = 68-105.

(2) Heat resistance of 360°C, for continuous use = up to 250°C.

(3) The value of wear of brake linings = is 5 x 10^{-4} - 5 x 10^{-3} mm^2/kg.

(4) Coefficient of friction = 0.14 – 0.27.

(5) The mass of the type of brake lining = 1.5 - 2.4 g/cm^3.

(6) Thermal conductivity = 0.12 - 0.8 Wm/K.

(7) Specific pressure = 0.17 - 0.98 J/g°C.

(8) Shear strength = 1300 - 3500 N/cm^2.

(9) Strength of fracture = 480 - 1500 N/cm^2.

To determine the mechanical strength of composite materials, the reference test must be based on stipulated provisions such as the description above.

2. Method

This study varied the addition of bamboo fiber, while the dosage between MgO and epoxy resin was fixed. The addition of bamboo fiber fraction includes 40, 50, and 60% (See Table 1)

Table 1. Variation in composition between samples

Specimen	MgO (%)	Bamboo Fiber (%)	Epoxy Resin (%)
Composite 1	30	40	30
Composite 2	25	50	25
Composite 3	20	60	20

Steps for making specimens are in the following. First, we performed and checked the mass composition for each materials. Then, the each component was added and mixed. The mixing process used an electric stainless steel mixer with a rotating speed of around 13,600-15,700 rpm (adjusted to the Atomic Tuned 2 Pro brand) for 8 minutes. The mixed components were put into the mold and compacted under a specific condition. The compaction process was carried out by adding force into the mold. This process was carried out by loading 200 psi for 20 minutes. Finally, the pressed component was sintered at 180°C for 30 minutes using an electrical furnace.

3. Results and Discussion

In the process of making motorcycle composite brake pads, we varied the mixture composition. The following are the results of weighing of each composition: Composite 1, 2, and 3 contained 7.9998; 7.5874; and 7.3070 g of sample. Detailed information for the composition of each component is shown in Table 2.

Table 2. Heavy fraction

Specimens	MgO(gram)	Bamboo Fiber (gram)	Ratio of resin andhardener	Composite Weight (gram)
Composite 1	2.50	3.25	12:2	7.9998
Composite 2	2.00	3.80	10:2	7.5874
Composite 3	1.50	4.35	8:2	7.3070

Coefficient of friction. To determine the friction coefficient, determination of the torque (T) used in the following formula:

$$T = P/\omega, \quad (1)$$

where P is the electricity power and ω is the rotation. Then, applied $P = 24$ Watt and $\omega = 180$ rpm, we can get $T = 24/180 = 0.13$ Nm.

Specific the friction coefficient (μ) was calculated using the following formula:

$$\mu = T/\left(2 \cdot F_n \cdot r\right), \quad (2)$$

where F_n and r are the force applied and the diameter of rod, respectively. Then, applied the condition of $r = 0.3$ m and $F_n = 2.3 \cdot 9.8 = 22.54$ N, we can get $\mu = 0.13/\left(2 \cdot 22.54 \cdot 0.3\right) = 0.0096$.

Testing the value of ware rate. Before testing, we checked the weight of sample before and after testing. The wear rate test used the ASTM D3702-94 Standard with a load of 2.3 kg and a speed of 180 rpm. We found that there is an increase in the mass. However, the increases in the mass are less than 0.5%.

The calculation in determining the value of the wear rate of a material using the formula, as follows:

$$M = \left(M_a - M_b\right) / \left(t \cdot A\right), \quad (3)$$

where M is the value of wear rate, M_a is the composite initial weight (gram), M_b is the composite final weight (gram), t is the testing time (second), and A is the frictional cross section area (mm^2). The wear test results in 1800 seconds are shown in Table 3.

Table 3.Wear rate obtained during the testing

Specimens	M_a (gram)	M_b (gram)	t (second)	A (mm^2)	M (g/mm^2.s)
Composite 1	6.4265	6.4142	1800	289	$2.3644 \cdot 10^{-8}$
Composite 2	4.5902	4.5816	1800	289	$1.6532 \cdot 10^{-8}$
Composite 3	4.0517	4.0467	1800	289	$0.9612 \cdot 10^{-8}$

From the results of testing the wear rate, the best wear resistance value occurs in the small value of the wear rate that is in the third specimen. So, by increasing the composition of bamboo fiber, the lower the wear rate of brake lining samples was obtained. This informs the material to be more resistant to wear [15].

Hardness test. The hardness test on the composite results and compares with the hardness value of the Rockwell Hardness of Plastics and Electrical Insulating Materials. This testing is important for understanding the effect of additional component into the material [16-20]. The testing procedure was carried out using ASTM D 785-03 type R with an indentor diameter of 12.7 mm and a minor load of 10 kg and a major load of 60 kg. The results of hardness testing are shown in Table 4.

Based on the three specimens, the addition of bamboo fiber has an impact on the hardness of the material. The more amount of bamboo fiber was added, the harder the material can be obtained [21]. Based on the safety standards, the mechanical properties of composite brake pads are in the standard safety range of 68.3-91.8 HRR (safety standard composite brake pads 68-105 HRR).

Table 4. Composite hardness value

Specimens	Rockwell R hardness value(HRR)			Average value of hardness (HRR)
	Testing number			
	1	2	3	
Composite 1	67.50	67.00	70.50	68.30
Composite 2	72.00	97.00	98.00	89.00
Composite 3	89.00	93.50	93.00	91.80

Calculation of lifetime of Composite Brake Shoes. To find out the lifetime of composites, we used the following formula:

$$U\left(n\right) = M_a / M_i, \quad (4)$$

where $U\left(n\right)$ is the lifetime (days), M_a is the initial brake pad mass (gram), M_i is the mass wasted in 1800 seconds (gram). The calculation results of each composition are shown in Table 5.

When compared with other compositions, the third composite has a relatively long usage of age compared to the first and second composites. This informs that the third composite is able to survive with the optimum specifications for 810 days.

Table 5.The lifetime of composite brake pads

Specimens	Initial Mass (gram)	Gram wasted/ 800 seconds	Time	Second	Hour	Day
Composite 1	6.4265	0.0123	523	941400	261.50	523
Composite 2	4.5902	0.0086	534	961200	267.00	534
Composite 3	4.0517	0.0050	810	1458000	405.00	810

Heat resistance testing. Heat resistance testing was done using an electrical furnace with the following regulatory specifications: processing time to reach a maximum temperature from room temperature is 7 minutes, holding time at the specific temperature is 10 minutes, and the testing temperature is 230°C. Each sample was done twice.

The following images paneled in Fig. 1 are the results of heat resistance testing. The condition of composite 1 (Figs. 1a and 1b) did not burn or burn due to heating, but the color of the specimen looks darker before heating the furnace. The condition of composite 2 (Figs. 1c and 1d) did not burn or scorch like a composite 1, but the color appears slightly dark compared to the initial state. The condition of composite 3 (Figs. 1e and 1f) did not burn or scorch like composites 1 and 2, but there is a difference other than the color that appears slightly dark and the bamboo fiber looks black.

(a) (b) (c) (d) (e) (f)

Fig. 1. Image of condition before-after heat testing. Figures (a) and (b) are for composite 1, Figures (c) and (d) are for composite 2, and Figures (e) and (f) are for composite 3

Based on the three specimens, there was no fire at all in the testing specimens. In this test, the brake lining specimens made from composites were better than ordinary brake pads made from asbestos, which could survive up to temperatures of 200°C [5].

4. Conclusions

Based on the data and analysis of the calculations, it can be concluded that bamboo is effective to be used. The best constituent material is in the third composite because it has the best mechanical properties, such as the wear rate of $0.9612.10^{-8}$ g/mm^2 (in which this can remain up to 810 days (2 years and 3 months)), hardness value of 91.8 HRR, and having good heat resistance (because there is no fire or burning phenomena during the testing specimen). This study demonstrates that natural based renewable materials from bamboo has good mechanical strength, giving information for the potential usage in motorbikes safely.

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