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MECHANICAL PROPERTIES OF SAWDUST AND RICE HUSK BRAKE PADS WITH VARIATION OF COMPOSITION AND PARTICLE SIZE

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Abstract

This research was conducted to determine the effect of variations in particle size and composition of brake pad (S) sawdust and rice husk (RH) as materials for making brake pads. This research was conducted by mixing sawdust (S) and rice husk (RH) particles with resin as the adhesive. Sawdust (S) and rice husk (RH) in the mesh using a mesh sieve (74: 250: 500 µm). Brake pads are prepared with seven variations. After that, the mixture was formed into the mold measuring 1.44 cm^3 and dried at room temperature. The brake pads were then tested using a characteristic test and wear test. From the test results obtained results that at the particle size variation of 74:250:500 µm with a ratio of G (1/1/2) obtained the best wear test results, with the lowest mass loss, the best puncture test, and optimal hardness test. This is because the brake pads with a particle size composition of G (1/1/2) are dominated by small particles so that they have a very tight distance between particles, which can increase density. However, it also requires large particles to provide distance so that the resin fills the area between them. This research is expected to provide information about the effect of variation in particle size on brake pads made from a mixture of sawdust and rice husks with resin as the matrix.

Keywords: Brake pads, Combination of sawdust and rice husk, Variation of particle size.

1. Introduction

Brake pads are one of the most important components of a vehicle braking system because they help convert the kinetic energy of the vehicle into heat energy [1]. Brake pads are placed on the wheel assembly so that it can hold the wheel which serves to slow or stop movement [2]. Commercial vehicle accidents rarely occur due to brake failure, but often due to a lack of brake pads [3]. Brake pads generally consist of natural asbestos and several other materials [4]. However, the use of asbestos is avoided in several countries such as the United States, United Kingdom, Colombia, Japan, and several other countries because asbestos has carcinogenic properties that can lead to cancer [5].

Researchers have switched to the use of non-asbestos brake pads derived from organic materials as an alternative to avoid the adverse effects of the use of asbestos material [6]. Current global research on brake pads mostly focused on biomass, which is often used as an environmentally friendly industrial raw material waste [2]. A mixture of rice husk and sawdust can be used as a biodegradable material which is processed into one of the developments of different eco-friendly products [7]. Many studies on the use of different biomasses and their extracts have been carried out as materials in the development of various eco-friendly products, such as the carboxymethyl cassava starch/polyurethane dispersion blend [7], study of types of plasticizers for biobased microcrystalline cellulose polylactic acid composites [8], and development of tea waste/kakap fiber composite paper [9]. Research on brake pads made from biomass has been done a lot, such as brake pads made from palm kernel fibers (PKFs) [10], palm kernel shells [11], coconut husk [12], corn husks [2], sawdust [1], banana peels [4], rice straw and rice husk dust [13], maize husks [2], chamaerops Fruit Shell [14], and eggshell particles [15].

Previous studies conducted by other researchers have found that there are four modes of operating failure during braking due to chemical changes, thermal instability, wear mechanisms, and micro-cracks that occur in the microstructure of the material used for brake pads [16]. Therefore, it is very important to develop and make the function of the materials used for brake pad applications more optimally into brake pads so that the braking operation does not fail by considering the four failure modes of braking operation. In this case, knowledge of the method of selecting materials to be used is very important.

Therefore, this study aims to determine the effect of variations in particle size and composition combinations on brake pads made from asbestos-free sawdust and rice husks. The biomass materials that can be used for brake pads are sawdust (S) and rice husk (RH). The use of rice husks has the potential to become brake pads material because it has silica in it which gives it properties physical such as ceramics [13]. While sawdust has thermal characteristics that have the potential as an alternative to brake pads and has a stable condition where the mass loss is not too large with a mass loss of only 18-20% [17]. The test is carried out by using the characteristic test (puncture test and hardness test) and wear test. The results showed that the particle size and combination of sawdust (S) and rice husks (RH) could affect the performance of brake pads. Larger particle sizes can create pores in the brake pads which can affect the performance of the brake pads. This study provides new information regarding the effect of particle size and compositional combinations that can be used for the development of brake pad quality.

2. Method

2.1. Materials and methods

The main materials used were sawdust (S) which was obtained from the waste of furniture and furniture production in the Cibinong area, Cianjur Regency, Indonesia; and rice husk (RH) obtained from waste of rice mills in the Cibinong area, Cianjur Regency, Indonesia. The resin type clear polyester and the catalyse were obtained from the city of Semarang, Indonesia which was purchased online. The tools used were digital scales, mesh sieves, and moulds.

In this study, there were two variations, specifically variations in particle size and variations in the combination of particle size composition of sawdust (S) and rice husks (RH). Detailed variations are shown in Tables 1 and 2. Figure 1 shows the steps for making brake pads. Sawdust (S) and rice husk (RH) were filtered using a mesh sieve with sizes of 500, 250, and 74 µm. Then S and RH were grouped based on particle size and combination of particle size composition. After that, S and RH which had the same particle size and combination of particle size composition were weighed and mixed in a ratio (1:1). Furthermore, a mixture of resin and catalyst was made in a ratio (1g:1 drops), the measurement of the catalyst was carried out using a dropper. Then the biomass was mixed with a mixture of catalyst resin (1:1). The catalyst serves to accelerate the resin hardening reaction because the resin will not harden properly without being mixed with the catalyst. The material that had been mixed evenly was formed by putting it in a 1.44 cm^3 mold and dry it at room temperature for 1 day. After that, the brake pad was taken out from the mold. Finally, the brake pad was ready to be tested.

Table 1. The variation used in this study with the ratio of S and RH are 1:1.

Type	Sample	Sawdust	Rice Husk
Particle Size	A	74 µm	74 µm
	B	250 µm	250 µm
	C	500 µm	500 µm

Table 2. Variation ratio of particle size (74:250:500 µm).

Type	Sample	Sawdust	Rice Husk
Combination of Particle Size Composition	D	1/1/1	1/1/1
	E	2/1/1	2/1/1
	F	1/2/1	1/2/1
	G	1/1/2	1/1/2

2.2. Testing

2.2.1. Friction test

The friction test is expressed in the material reduction of each unit of contact area and the duration of friction [18].

$$M = \frac{w_0 - w_1}{A.t} \quad (1)$$

where M is the wear rate ($g/mm^2.s$), w_0 is the initial weight of the lining before wearing (g), w_1 is the final weight after wear (g), A is the area of the brake pad under test (mm^2), and t is the wear time (s).

The coefficient of friction (μ) is the ratio of the friction force (f; Newton) to the applied force (*N*; Newton) in the following equation.

$$\mu = \frac{f}{N} \tag{2}$$

where *f* is the friction force (*N*), and *N* is the normal force (*N*).

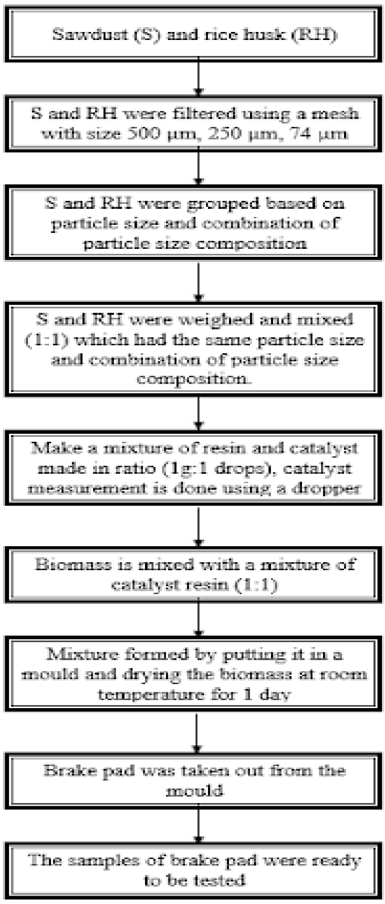

Fig. 1. Flowchart manufacture of brake pads.

2.2.2. Mechanical properties test wave drag coefficient

Several mechanical properties are in the following:

(i) Puncture Test. The puncture test is the mechanical test to measure the strength of the sample. In this study, the puncture test was carried out by testing seven variations of brake pads (S) and (RH) using the Shore Durometer instrument (Shore A Hardness, In size, China). During the test, a probe is used to puncture the brake pads. Hardness is measured on a scale of 0 to 100.

(ii) Hardness Test. The hardness test is a mechanical test for the properties of a material used in structural analysis and material development. In this study, hardness testing was carried out by testing seven variations of brake pads using a Screw Stand Test Instrument (Mode I ALX-J, China) equipped with a measuring instrument (Digital Force Meter (Model HP500, Serial). No. H5001909262)). The test is performed by applying a constant displacement rate of 2.60 mm/min to the brake pad. The compression forces are recorded simultaneously, resulting in a curve that shows the hardness of the brake pads' texture. The compressive strength is then obtained from the maximum point of the compressive stress-strain curve. Additionally, density (ρ) is calculated using the following equation.

$$\rho = \frac{m}{v} \tag{3}$$

where ρ is the density, m is the mass of the brake pad, and v is the volume of the specimen brake pad (v = 1.2×1.2×1.0) = 1.44 cm^3.

3. Results and Discussion

3.1. Physical appearance of brake pads

Figure 2 shows an image of brake pads with variations in particle size and variations in composition combinations particle size. Figures 2(a)-(c) show images of brake pads with varying particle sizes (A, B, and C). Figs. 2(d)-(g) shows images of brake pads with various combinations of particle sizes (D; E; F; and G). The observed surface of the brake pads shows that the large particle sizes have a darker colour than the small particle sizes. Figure 3 shows the pore surface of brake pads at variations in particle size and variations in the combination of particle size compositions. Figures 3(a)-(c)show the number of pores and the size of the pores on brake pads with various particle sizes (A, B, and C). Figures 3(d)-(g) shows the number of pores and the size of the pores on brake pads with various combinations of particle sizes (D; E; F; and G). The number of pores and the size of the pores on the brake pads shows that the large particle size has larger and larger pores compared to the small particle size.

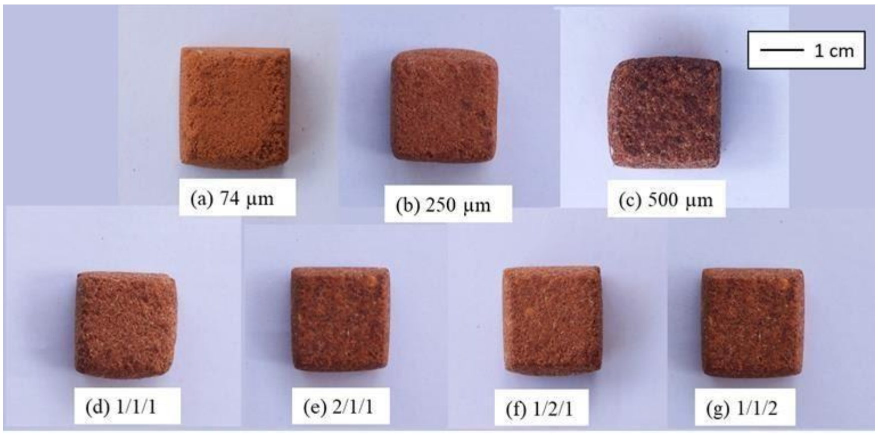

Fig. 2. The surface of the brake pads (S) and (RH).

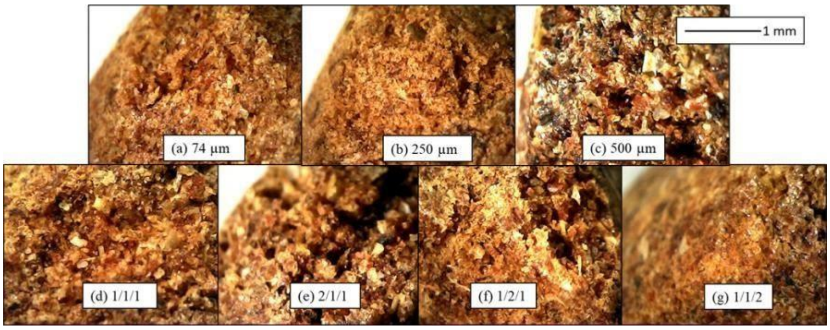

Fig. 3. Brake pad pores.

3.2. Friction Test

Figure 4 shows the influence of particle size variations and particle size composition on sawdust (S) and rice husk (RH) mixture brake pads against mass loss. From the test results obtained those variations of brake pads, A obtained the lowest mass loss value and brake pads with variation C obtained the highest mass loss value. The large particle size will be easily eroded so that the resulting mass loss value will be higher than the size of small particles from the brake pads. The high mass loss value causes high wear, which is in line with the results of other studies. Particle testing of brake pad material wear can provide useful information about the wear mechanism [19]. During friction testing, the brake pads are subjected to frictional forces due to two objects intersecting in opposite directions. The friction process that occurs causes deeper friction on the surface of the composite with larger particles so that the particles are easily separated from the surface. This happens because the distance formed between the pores is large enough to cause the catalyst resin to not bond strongly. Meanwhile, small particle composites are not easily removed from the surface of the brake pads because the pores formed are very tight so that the resin and catalyst easily bind to the biomass and strengthen the composite surface. Small particles have a better particle distribution for resistance to friction. However, small particles have a very high wear rate because they have a large surface area compared to large particles. The large surface area causes more particles to be lost during the friction test. Larger particles increase the tendency of small particles to leave the matrix. Conversely, larger particles are expected to be embedded in the matrix until they break down into smaller particles to reduce the wear rate of the brake pads [20].

Table 3 is the result of test data on brake pads made from sawdust (S) and rice husk (RH) using Eqs. (2) and (3). The test results showed that the highest coefficient was obtained by brake pads with a variation of B namely 0.66, while the lowest was obtained from the variation of E with a coefficient value of 0.21. Changes in the coefficient of friction affect braking. The more fibers content in the composite brake pad, the braking that occurs will be better. This is because the fibers that appear on the friction surface create a contact area between the elastic fibers and the stiffness of the friction partner. So that the more fibers that appear on the surface, the higher the coefficient of friction produced during testing [21]. The wear rate of the friction brake material is a complicated and non-steady-state because the variability in operating conditions is influenced by the characteristics of the brake pad material [22]. Generally, the value of the coefficient of stable friction depends on the composite and the load applied, and this is very important for brake pads applications [23]. In addition, hard particles in the composite produce larger deformations due to rough interactions during the friction test and this affects the coefficient of friction [24].

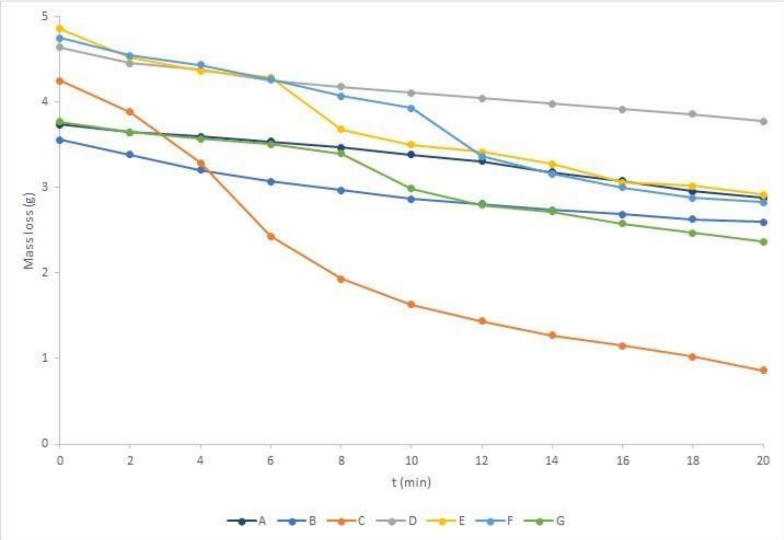

Fig. 4. Comparison of brake pads of various variations.

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Table 3. Wear test results on variations in particle size and composition of brake pads (S) and (RH).

Sample	Ma (g)	Mb (g)	Mass loss rate (g/min)	M (g / s.mm^2) ($\times 10^{-6}$)	Friction coefficient
A	3.74	2.88	0.04	1.042E-07	0.58
B	3.56	2.50	0.05	1.164E-07	0.66
C	4.25	0.86	0.17	4.52E-07	0.38
D	4.64	3.78	0.04	1.042E-07	0.27
E	4.86	2.92	0.07	2.352E-07	0.21
F	4.75	2.83	0.09	2.327E-07	0.24
G	3.77	2.37	0.1	1.697E-07	0.56

Figure 5 shows the comparison between the brake pads in this study, namely using a mixture of sawdust (S) and rice husks (RH) using polyester-type resin as the matrix material. From Fig. 5, it can be seen that brake pads with a mixture of (S) and (RH) have a relatively higher mass stability than conventional pads, so they can be categorized as brake pads that are not wasteful and are durable to friction. The results show biomass-based brake pads support impact stress resistance results because this structural formation increases the inner hardness of the brake pads, so those biomass-based brake pads improve the thermal stability of friction nanocomposites. It can be concluded that biomass-based brake pads showed excellent mechanical properties compared to brake pads in general [1]. The high hardness of biomass-based brake pads is attributed to the increase in bonding and close packing that the density in the composite brake pad raised its hardness [2].

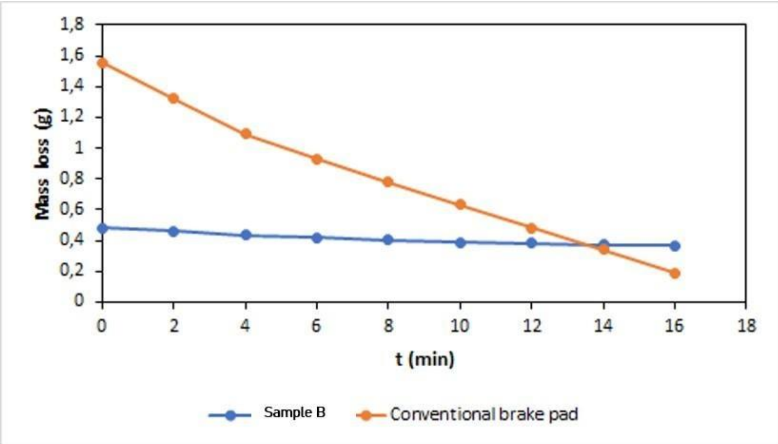

Fig. 5. Comparison of brake pads (S) and (RH) with conventional brake pads.

3.3. Friction test

3.3.1. Puncture test

Table 4 shows the results of the puncture test on brake pads (S) and (RH). Brake pads (S) and (RH) with a variation of A has an average value of 82; variation B has an average value of 77.20, variation C has an average value of 74.5; variation D has a mean value of 72; variation E has an average value of 79, variation F has an average of 82 and variation G has a mean of 85.16. The results showed that the highest value of the puncture test was owned by brake pads with variation G, while the lowest value was owned by brake pads with variation D. Comparison of G composite brake pads was dominated by large particles with more stretchable distances between particles than other brake pads variations. This causes the resin to fill more in the strain area so that the brake pads are tighter and produces a high puncture test value [25]. In addition, the puncture will be more difficult to penetrate large particles than through small particles of saws and rice husks. A larger force is required to penetrate saw and rice husk particles considering the higher strength of saw and rice husk particles compared to resin, according to the study [26]. In addition, the larger particle size of the brake pads in this variation makes it easy to puncture, this is because the brake pads matrix material with larger particles has a fairly soft texture so that it affects the puncture test value [27].

Table 4. Puncture Test Results of variations in particle size and composition of brake pads (S) and (RH).

	A	B	C	D	E	F	G
Average	82.00	77.20	74.50	72.00	79.00	82.00	85.16

3.3.1. Hardness test

Figure 6 shows the results of the hardness test of 7 variations in the composition of the brake pads (S) and (RH). Brake pads (S) and (RH) have an average hardness test value, namely variation A of 27.10; variation B of 16.67; variation of C by 21; variation D of 16.46; variation E of 15.35; F variation of 26.23; and variation G has an average value of 30.93. The results showed that the highest value of hardness was owned by the brake pad with variation G, while the lowest value was owned by the brake pad with variation E. Hardness test was carried out to determine how strong the brake pad was to withstand the load received. In brake pads, the decrease in the material during the testing shows the level of brake pad hardness, the tightness of the distance between particles will affect the hardness of the brake pads [28]. The results of this study are inversely proportional to research [2] which resulted in this study that a high particle distance did not result in a high hardness test. The different results are because the materials (S) and (RH) can absorb the resin so that the distance between the particles is not the main factor affecting the hardness test value. This is in accordance with previous studies that resin can be used as a binder for unsaturated polyester as a matrix and bonding material because biomass can act as an absorbent [11]. In addition, the high hardness is caused by an increase in density which causes the interaction of smaller biomass particles with the resin as a binder which will harden the composite brake pad and increase its hardness [2]. The present study is in agreement with previous reports [29-33].

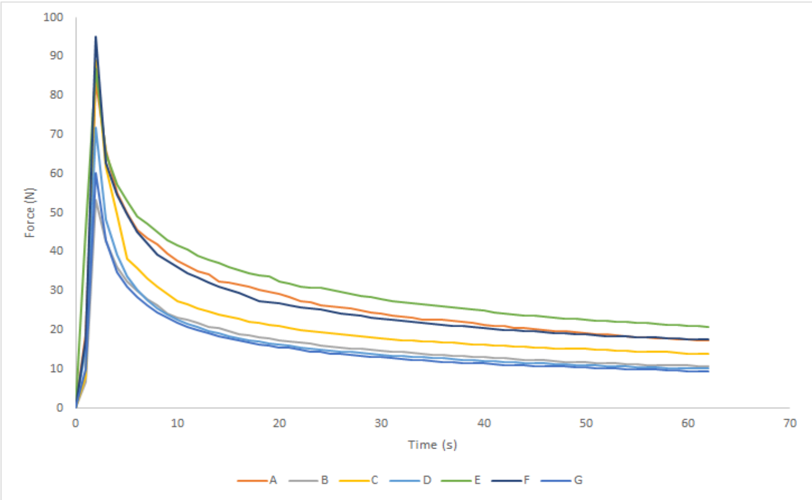

Fig. 6. The results of the hardness test of variations in particle size and composition of (S) and (RH).

4. Conclusion

From this study, it can be concluded that biomass can be used as a material for making brake pads. The effect of particle size variation and composition combination affects the quality of the brake pads. Brake pads dominated by small particles in the G variation have good strength and are durable with high friction values. This is because S and RH composites can absorb resin well, small size particles can increase density. However, small particles still need large particles to provide a considerable distance so that the resin fills the area between them.

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Nomenclatures

A	Area of the brake pad under test, mm^2
f	Friction force, N
M	Wear rate, $g/mm^2.s$
m	Mass of the brake pad, kg
N	Applied force, N
T	Wear time, s
V	Volume of the specimen brake pad (v = 1.2×1.2×1) = 1.44, cm^3
w_0	Initial weight of the lining before wearing, g
w_1	Final weight after wear, g

Greek Symbols

μ	Coefficient of friction
ρ	Density, kg/m^3

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