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Hardness and Wear Analysis of Brake Pads Made from Sugarcane Bagasse and Iron Powder as *Epoxy Matrix Reinforcement*

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Abstract: Brake lining is a component that has the function of slowing or stopping the speed of a vehicle. Brake linings sold on the market are generally made from asbestos which is not friendly to health and the environment. Therefore, there is a need for alternative ways of making brake linings with materials that are safe for health and the environment, one of which is by using sugarcane bagasse waste, seeing that the nature of sugarcane bagasse is fibrous so it has the potential to be used as an alternative material for brake lining mixtures. The aim of this research is to analyze the best hardness and wear of composite brake pads made of bagasse material and iron powder as reinforcement with an epoxy matrix through the Shore D hardness test and Oghosi wear test, with the composition of bagasse ranging from 35%, 40%, 45% varying with iron powder of 15%, 10%, 5% and mixed with 50% epoxy resin with the same content. Shore D hardness test results obtained the highest hardness, namely at a volume fraction of 35%: 15%: 50% with a value of 72.5 HD. In the Oghosi wear test results, the lowest wear was in the volume fraction of 35% : 15% : 50% with a wear value of 0.000203 Ws;mm 3 /kg.m. The results of this research show that the large percentage of bagasse and iron powder mixed will affect the hardness and wear values of the brake pads.

Keywords: Brake lining, bagasse, iron powder, hardness test, wear test.

INTRODUCTION

The development of automotive technology continues to increase with the increasing demand for transportation equipment, especially motorized vehicles. Currently, motorized vehicles generally have very high speeds in line with technological advances in motorized vehicles. The development of engine performance must of course be balanced with a good braking system for driving safety. The braking system functions to slow down or stop the speed of the vehicle. A brake system that is not functioning properly is often caused by wear on the brake discs and linings due to friction. So the brake lining construction is made from materials that have good and effective capabilities to achieve optimal braking performance (Lili Mulyani, 2022).

The materials for brake linings sold on the market are asbestos, steel fiber, cellulose, rock wool, graphite and Kevlar. The brake lining material in circulation raises concerns because of its dangerous particles. Uses such as asbestos have been banned because they can harm respiratory health if inhaled (Kosjoko, 2021) . This encourages us to look for alternative ways to make brake linings using materials that are safe for health and the environment. Various agricultural wastes and industrial wastes have emerged as economical alternative raw materials. One of the agricultural wastes that is widely available in Indonesia is bagasse *waste* . So far, the use of bagasse as organic fertilizer, animal feed and boiler fuel has been limited and has low economic value. The nature of sugarcane bagasse is fibrous, so it has the potential to be used as an alternative material for brake lining mixtures.

In a study on brake linings conducted by (Sugianto and Arlini, 2020) made from variations of bagasse, aluminum powder, brass powder with variations in size without sieve, 50 mesh, 100 mesh, and with

composition variations of 50% bagasse, 25% aluminum powder, 25% brass powder, 40% bagasse, 30% aluminum powder, 30% brass powder, 30% bagasse, 35% aluminum powder, 35% brass powder. The results of this research showed that the optimum level of vikers and impact hardness was found in a composition of 50% bagasse, 25% aluminum powder, 25% brass powder and 1:1 epoxy resin with a size of 50 mesh, namely 18.90 HVN, while in the wear level test The minimum contained in the composition of 50% bagasse, 25% aluminum powder, 25% brass powder and 1:1 epoxy resin with a size of 50 mesh is 0.22 joules/mm.

From the background above, the author is interested in conducting research on alternative brake lining materials made from bagasse and iron powder as reinforcement and epoxy resin as the matrix. Several previous studies have conducted research on composite materials reinforced with bagasse, but by varying the sieve size and varying the volume fraction without a carbonization process. In this research, sugarcane bagasse fiber was used using an alkaline treatment process which was then combined with iron powder. The expected result of this research is that brake linings have good hardness properties and are resistant to wear, and can be used as an alternative to asbestos brake linings.

RESEARCH METHODS

This research method is an experimental research method which aims to determine the effect of the independent variable (*treatment*) on the dependent variable (outcome) under controlled conditions. Conditions are controlled so that no other variables (other than the *treatment variable*) influence the dependent variable (outcome). So that conditions can be controlled, experimental research uses a control group and along with experimental research it is carried out in the laboratory.

This research will be carried out at the Engineering Laboratory of the Muhammadiyah University of Jember and the hardness test will be carried out at the Engineering Laboratory of the State University of Malang and the wear test will be carried out at the Engineering Laboratory of Gajah Mada University Yogyakarta.

Materials and tools

The materials used for research are:

1. Sugarcane bagasse
2. Iron powder
3. Epoxy resin 108
4. NaOH 5%

The tools needed in research are:

1. Measuring cup

A measuring cup is used to determine the volume composition of materials including bagasse, iron powder, and epoxy resin 108 as in Figure 4.

Figure 4. Measuring Cup

2. Hand Grinding

A grinder is used to shape the specimen according to ASTM as in Figure 5.

Figure 5. Hand Grinder

3. Blender

A blender is used to smooth the bagasse as in **Figure 6** .

Figure 6. Blender

4. 50 mesh sieve

A sieve is used to separate coarse bagasse from fine bagasse with a size of 50 mesh as in **Figure 7** .

Figure 7. 50 mesh sieve

5. Mold

A mold is used to form the specimen as in **Figure 8** .

Figure 8. Specimen mold

6. Calipers

Vernier calipers are used to measure the thickness of the brake lining as in **Figure 9** .

Figure 9. Caliper

Research variable

In a study there are several types of variables that are composed of various components such as factors, attributes, and treatments that will be taken based on research studies.

1. Dependent Variable

The dependent variable is the variable determined by the researcher before conducting the research. The test was carried out by varying the bagasse and iron powder mixed with 108 epoxy resin treated with 5% NaOH. Research samples were taken to see several comparisons of the composition of bagasse, iron powder and epoxy 108 resin with 5% NaOH treatment.

2. Controlled Variables

Controlled variables are variables created in a study. This test was carried out by varying sugar cane bagasse with values of 35%, 40%, 45% and iron powder 15%, 10%, 5% mixed with 50% epoxy resin and treated with NaOH 5 %. Research samples were taken to see several comparisons of the composition of bagasse, iron powder, and epoxy 108 resin with 5% NaOH treatment.

Table 1. Variations in Brake Pad Mixtures

Bagasse (%)	Iron powder (%)	Epoxy Resin 108 (%)
35%	15%	50%
40%	10%	50%
45%	5%	50%

Source: Doc. Personal

3. Independent Variable

An independent variable is a variable whose size cannot be fully determined by the researcher, but the size depends on the dependent variable. This research has independent variables which include data obtained from *Shore D Hardness Durometer hardness testing* and *Oghosi wear* .

Research procedure

The research procedures carried out by researchers are as shown in **Figure 10** .

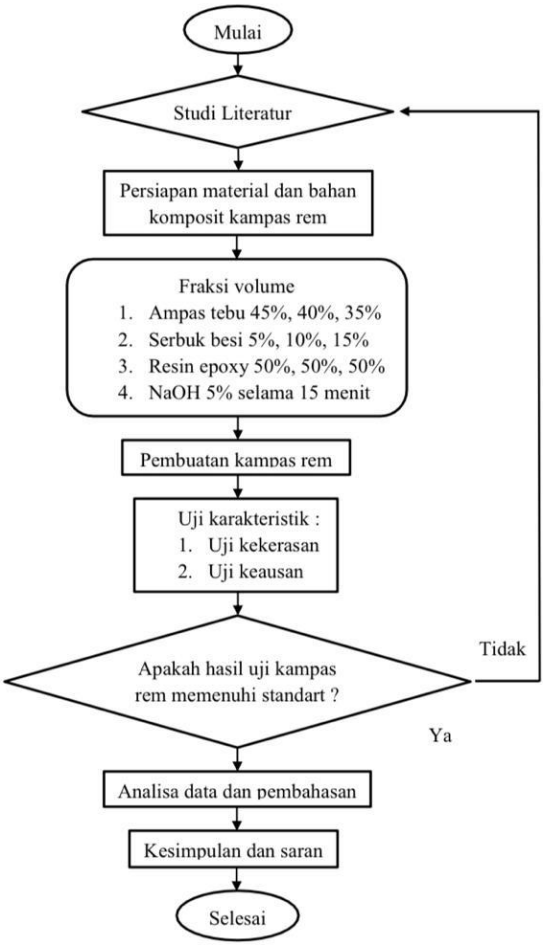

Figure 10. Research Flow Diagram

Source: Doc. Personal

RESULTS AND DISCUSSION

A. Data Analysis of Shore Durometer Hardness Test Results D

Figure 11. Brake Pad Specimen Sample

Source: Doc. Personal

Brake lining specimens with a composite material of bagasse and iron powder with an epoxy matrix, specimen samples with different volume fraction groupings as in **Figure 11** .

This hardness test was carried out using the durometer test method. From the research that has been carried out, the results of the brake lining hardness test using bagasse material and iron powder with an epoxy matrix will be discussed, where each specimen will be compared in **Table 2** and **Figure 12** as follows:

Table 2. Table *Shore D Hardness Durometer* Hardness Test Results

No	Code Specimen	Number Specimen	Violence (HD)			Average value		
			Point 1	Point 2	Point 3	Point 1	Point 2	Point 3
1	Bagasse: 35%	1	63.5	64	64.5	71.6	71.3	72.5
2	Iron powder : 15%	2	76.5	77	78.5			
3	Epoxy resin: 50%	3	75	73	74.5			
4	Bagasse: 40%	1	69	71.5	72	69.5	70.5	71
5	Iron powder : 10%	2	72.5	72.5	73			
6	Epoxy resin: 50%	3	67	67.5	68			
7	Bagasse: 45%	1	57	58.5	59	59.8	59.6	60.1
8	Iron powder : 5%	2	58.5	56	58			
9	Epoxy resin: 50%	3	64	64.5	63.5			

Source: Doc. Personal

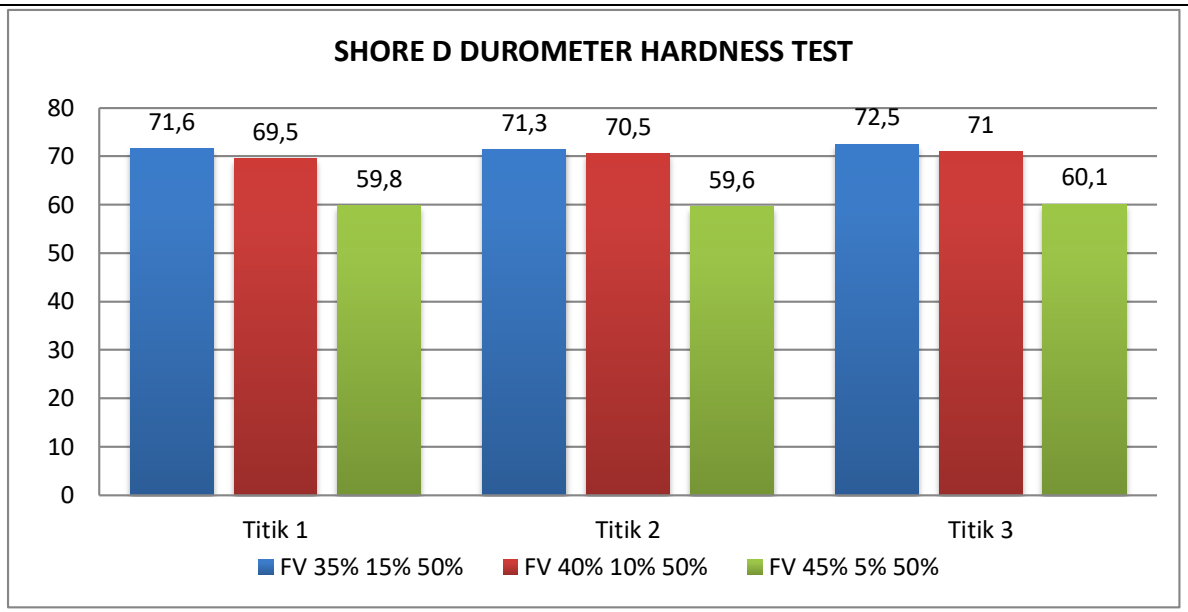

Figure 12. Durometer hardness test graph Source: Doc. Personal

Information :

Brake Pad Mix Variations

1. 35% Sugarcane Bagasse + 15% Iron Powder + 50% Epoxy Resin
2. 40% Sugarcane Bagasse + 10% Iron Powder + 50% Epoxy Resin
3. 45% Sugarcane Bagasse + 5% Iron Powder + 50% Epoxy Resin

The results of the Shore D Durometer hardness test with the volume fraction of a mixture of bagasse and iron powder with epoxy resin obtained the highest hardness results, namely in the specimen mixture of 35% bagasse + 15% iron powder + 50% epoxy resin which obtained a value of 71.6 HD at point 1 , at point 2 you get a hardness value of 71.3 HD, and at point 3 you get a value of 72.5 HD because the first specimen has the lowest mixture of bagasse and the highest iron powder, namely 15%, so the more iron powder reinforcement mixture it will make the specimen harder.

The results of the hardness test on the volume fraction of 40% bagasse + 10% iron powder + 50% epoxy resin obtained intermediate results, namely a value of 69.5 HD at the first point, at the second point it was 70.5 HD, and at the third point it was 70.5 HD. 71 HD.

The results of the hardness test on the volume fraction of 45% bagasse + 5% iron powder + 50% epoxy resin got the lowest hardness results, namely with a value of 59.8 HD at point 1, at point 2 it got a value of 59.6 HD, and at point 3rd is 60.1 HD. So the more sugar cane bagasse mixed, the lower the hardness value of the specimen.

Table 3. Table of comparison results of hardness tests according to SNI standards

No	Researcher's name	Volume fraction	Hardness test results
1	Hardness value according to SNI standards	-	68-105 (Rockwell R)
2	Joko Hari Prasetyo	35% bagasse + 15% iron powder + 50% epoxy resin	72.5 HD
3	Joko Hari Prasetyo	40% bagasse + 10% iron powder + 50% epoxy resin	71 HD
4	Joko Hari Prasetyo	45% bagasse + 5% iron powder + 50% epoxy resin	60.1 HD

Source: Doc. Personal

The standard hardness test requirement according to SNI is 68-105 Rockwell. In research conducted by the author, number 2 with a mixed volume fraction of 35% : 15% : 50% got the highest hardness value, namely 72.5 HD, and number 3 with a mixed volume fraction of 40% : 10% : 50% got the value hardness is 71 HD, and number 4 gets a value of 60.1 HD with a mixed volume fraction of 45% : 5% : 50%.

***Oghosi* Wear Test Results**

Testing was carried out with an Oghosi wear tester. Thus, the wear test for brake linings from composite materials made of sugarcane bagasse and iron powder with an epoxy resin matrix mixed with different volume fractions will be compared in **Table 4** and **Figure 13** below:

Table 4. Table of *oghosi* wear test results

No	Specimen Code		b0 value (mm)	B (mm)	r (mm)	P0 (kg)	l0 (m)	Specific wear (ws) (mm³/kg.m)	Average (ws) (mm³/kg.m)
1	Bagasse: 35%	1	1.2068	3	13.06	6.36	66.6	0.000119	0.000203
2	Iron powder : 15%	2	1.6564	3	13.06	6.36	66.6	0.000308	
3	Epoxy resin :50%	3	1.3928	3	13.06	6.36	66.6	0.000183	
4	Bagasse: 40%	1	1.5140	3	13.06	6.36	66.6	0.000235	0.000342
5	Iron powder : 10%	2	1.5536	3	13.06	6.36	66.6	0.000254	
6	Epoxy resin :50%	3	1.9916	3	13.06	6.36	66.6	0.000536	
7	Bagasse: 45%	1	2.7588	3	13.06	6.36	66.6	0.001423	0.000578
8	Iron powder : 5%	2	1.1920	3	13.06	6.36	66.6	0.000115	
9	Epoxy resin :50%	3	1.4264	3	13.06	6.36	66.6	0.000197	

Source: Doc. Personal

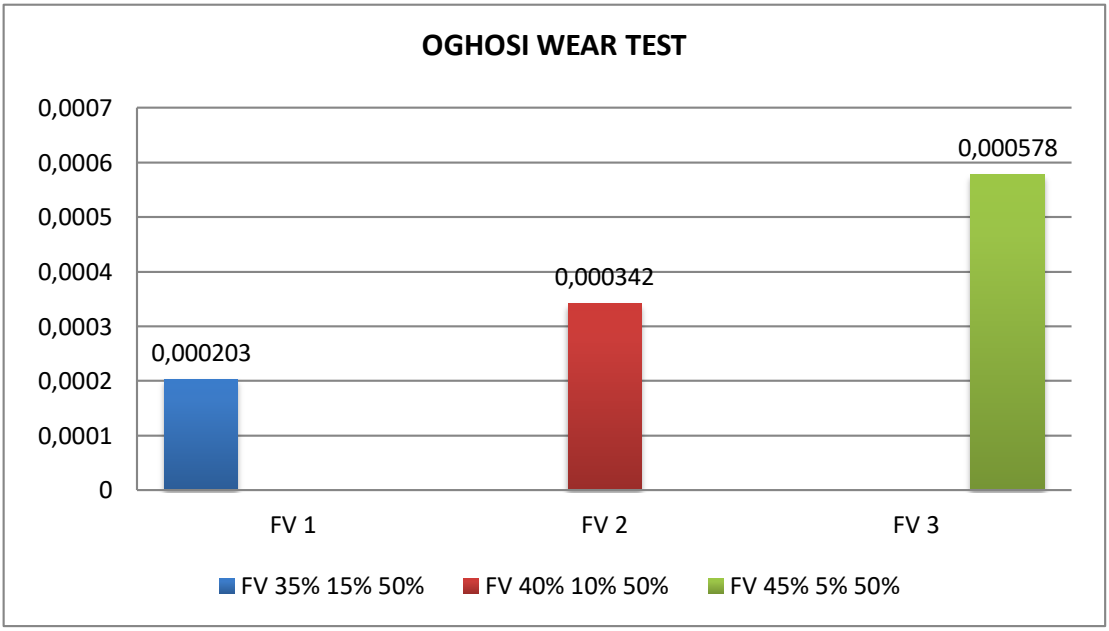

Figure 13. Graph of *oghosi* wear test results

Source: Doc. Personal

The results of the oghosi wear test of the composite material of bagasse and iron powder with an epoxy resin matrix on the first specimen with a volume fraction of 35% bagasse: 5% iron powder: 50% epoxy resin

at point 1 obtained a wear value of 0.000119 Ws;mm ^{3} / kg.m, and at the 2nd point it is 0.000308 Ws;mm ^{3} /kg.m, and at the 3rd point it is 0.000183 Ws;mm ^{3} /kg.m. This first specimen got the lowest wear value because it had the highest mixture of iron powder, namely 15% and the lowest mixture of bagasse, namely 35%.

In the second specimen with a volume fraction mixture of 40% bagasse: 10% iron powder: 50% epoxy resin at point 1, the wear result was 0.000235 Ws;mm ^{3} /kg.m, at point 2 it was 0.000254 Ws ;mm ^{3} /kg.m, and at the 3rd point it is 0.000536 Ws;mm ^{3} /kg.m, this second specimen gets a medium wear value because the mixture of bagasse is quite high and the mixture of iron powder is not so low.

In the 3rd specimen with a volume fraction mixture of 45% bagasse : 5% iron powder : 50% epoxy resin, at point 1 the wear result was 0.001423 Ws;mm ^{3} /kg.m, at point 2 got a value of 0.000115 Ws;mm ^{3} /kg.m, at point 3 we get a wear result of 0.000197 Ws;mm ^{3} /kg.m. The third specimen got the highest wear results, because the mixture of bagasse was very high, namely 45% and very little iron powder, namely 5%, which resulted in the specimen being easily worn because the powder was not strong enough to bind with the other mixtures.

Table 5. Table of comparison results of wear tests according to SNI standards

No	Name Researcher	Fraction Volume	Test results Wear
1	Appropriate Hardness Value SNI standard	-	5 x 10 $^{-4}$ – 5 x 10 $^{-3}$ Mm ^{2} /kg
2	Joko Hari Prasetyo	35% bagasse + 15% iron powder + 50% epoxy resin	203 x 10 $^{-6}$ mm ^{2} /kg
3	Joko Hari Prasetyo	40% bagasse + 10% iron powder + 50% epoxy resin	342 x 10 $^{-6}$ mm ^{2} /kg
4	Joko Hari Prasetyo	45% bagasse + 5% iron powder + 50% epoxy resin	578 x 10 $^{-6}$ mm ^{2} /kg

Source: Doc. Personal

Comparing the results of the wear test according to SNI standards with a value of 5 × 10 $^{-4}$ – 5 × 10 $^{-3}$ mm ^{2} /kg with research that has been carried out, in number 2 with a mixture volume fraction of 35% : 15% : 50% the average results were obtained. wear was 203 x 10 $^{-6}$ mm ^{2} /kg, and at number 3 with a mixed volume fraction of 40% : 10% : 50% the average wear result was 342 x 10 -6 ^{mm} 2 / kg, and at number 4 with Mixed volume fraction 45% : 5% : 50% produces an average wear result of 578 x 10 $^{-6}$ mm ^{2} /kg.

CONCLUSION

Based on research that has been carried out on the composite material of bagasse and iron powder with an epoxy resin matrix, it can be concluded that the influence of volume fraction on the Durometer hardness test for the highest hardness results is in the 1st volume fraction, namely with a mixture of 35% bagasse 15% iron powder and 50% epoxy resin with a value of 72.5 HD, because the 1st volume fraction has the highest mixture of iron powder, namely 15%, so the more iron powder mixed, the harder the specimen will be and the influence of volume fraction on the Oghosi wear test for the results The lowest wear was in the 1st volume fraction, namely with a mixture of 35% bagasse, 15% iron powder and 50% epoxy resin, with a value of 0.000203 Ws;mm ^{3} /kg.m, because the 1st volume fraction had a mixture of bagasse. The lowest is 35%, so the less bagasse is mixed, the less scratches the surface of the specimen or the lower the wear value.

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