The aluminum powder size’ effect on rice plant fiber reinforced composite to hardness, wear and coefficient of friction of brake lining

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Abstract. Composite particles are composites that contain particle or powder-shaped reinforcing materials. Particles as reinforcing materials greatly determine the mechanical properties of composites because they carry the load distributed by the matrix. The particle size, shape, and material are factors that influence the mechanical properties of particle composites. The friction component material that is intended for brake lining applications is strongly influenced by the size of the particles and the direction of loading. On the other hand it is necessary to step up the particle size optimization which will affect braking performance, which includes: friction numbers, wear, friction time and friction temperature produced. Therefore this study is aimed at optimizing the particle size against hardness, wear resistance and friction of aluminum powder in rice plant fiber reinforced composite. In this study, the materials used in the experimental process were rice plant fiber, fiberglass, aluminum powder and polyester resin. After the material is processed into the composite, hardness is tested using the durometer shore hardness method, after that, wear and friction testing were conducted. The results show the smaller the size of the aluminum powder, the harder the composite. The smaller the size of aluminum powder, the less wear of the composites. The failure of the adhesive was seen in the specimen tested for wear.

1. Introduction

The development of increasingly modern automotive makes the market demand for spare parts products even bigger. Brake lining is one component of a motorized vehicle that functions to stop motor vehicles. Brakes function to slow or stop the movement of the wheels so that the wheels move slowly. The kinetic energy lost from a moving object is converted to heat due to friction. If the brakes are not functioning properly, an accident is possible. The safety factor of the driver is very important. So that every motor vehicle manufacturer designs the system and uses brake components (brake lining) that are in accordance with the capabilities of the vehicle. Asbestos type brake lining is widely circulating at a cheap price and guarantees the durability of brake shoes, but the result of friction powder in the form of small particles is very dangerous for human health.

In the braking process, two materials will rub against each other and convert the motion energy into heat energy. At the time of friction, wear will occur in both materials. The constituent material for
brakes that is widely used is asbestos. Asbestos powder as a result of wear and tear can enter the body of a person so that it can cause disease. For this reason, research is needed on materials that can be used as a substitute for asbestos. Composite material has the potential to be used as a substitute material.

The availability and accessibility of abundant plant is the main reason for the emergence of new interests in sustainable technology, including interest in composite materials. When focusing on composite materials, the main points to consider are environmentally friendly and lightweight, non-toxic, with high mechanical properties [1-4].

There is an urgency to overcome concerns in the production of new materials for the environment and economy and hence in this case new materials based on plant and bio-resins must be able to produce green materials that are environmentally friendly [5]. The Indonesian government is currently promoting the achievement of the results of the nation's technology that can be applied or downstream. This becomes a policy which benefits: can minimize the import component, dependence on foreign products, develop the capabilities of its researchers, reduce imports, the existence and independence of the nation's technology. Along with the times and the emergence of government regulations, the public is made aware of the preservation of the environment.

The strength of the brake particle composite material is greatly influenced by the particle size, material of the matrix and the manufacturing process. The strength of particle composites was obtained at a maximum size of 0.01 to 0.1 mm and strength of surface bonding, pressing, and sintering [6]. The process is very rarely explained by friction lining producers, so there is a need for research on: materials and processes that are scientifically standard so that friction can be easily made, so it is necessary to develop this research continuously. When developing suitable brakes and friction pairs, engineers must consider various parameters such as braking interface temperature, braking applied, and speed that affect the process of surface friction in rough contact [7].

A composite is a combination of two materials in which one material, called a reinforcement phase, is in the form of fibers, sheets, or particles, and is embedded in another material called the matrix phase. The reinforcing material and matrix material can be metal, ceramic or polymer. Composites usually have a fiber or particle phase that is more rigid and stronger than the continuous matrix phase and serves as the main burden that carries members. The matrix acts as a medium to transfer loads between fibers or particles, and in less ideal cases where the load is complex. The fiber or particle is more brittle than the matrix, so the matrix acts as a source of composite toughness. This matrix also functions to protect fibers or particle from environmental damage before, during and after composite processing. When properly designed, new combined materials show better strength than each individual material. Composites are used not only for their structural properties, but also for electricity, thermal, tribology and environmental applications. Composite is a multifunctional material system that provides characteristics that cannot be obtained from discrete material. They are cohesive structures made by physically combining two or more compatible materials, differing in composition and characteristics and sometimes in form. Composites should not be considered simple as a combination of two ingredients. In a broader sense; the combination has its own characteristics. In terms of strength for heat resistance or some other desired quality, it is better than one of its own components or very different from both [8, 9].

Composite is a compound material that is different from alloy by the fact that individual components retain their characteristics but once incorporated into composites get better properties. Composite material as a heterogeneous material consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can also be regarded as homogeneous material on a microscopic scale in the sense that each part of it will have the same physical properties [10].

Interest in natural composite materials is growing rapidly both in terms of industrial applications and fundamental research. They can be updated, cheap, fully or partially recyclable, and can be decomposed. Their availability, renewable power, low density and price and satisfying mechanical properties make them an attractive ecological alternative.
Composite materials are actually abundant in nature, because composite materials can consist of organic and inorganic materials such as wood, bamboo, and leaves. Various types of composites have been unconsciously made. Clay strengthened with straw, is a composite that has long been known.

Manufacturing natural fiber composites is one of the real industry challenges today. This type of material offers economic and ecological advantages to promote sustainable development by producing recyclable products [11, 12].

Composite material composition affects mechanical properties. Zhao and friends [13] examined the effect of adding carbon nano tube to the coefficient of friction of carbon nano tube - hydroxyapatit composites. Addition of carbon nano tube 20% to hydroxyapatit will reduce the friction coefficient from 0.05 to 0.28. Xin and friends [14] found that the composite friction and wear resistance would be optimal if the ratio of sisal receipt and fiber was 3: 4.

Shalwan and Yousif [15] found that surface characteristics, volume fractions, physical properties and fiber directions had a significant effect on the mechanical properties of composites. In other words, the selection and modification of fibers is needed to improve the mechanical properties of composites.

From the considerations above, the researchers investigated the effect of the size of aluminum powder on the hardness, wear and coefficient of friction of aluminum in the rice plant fiber reinforced composite.

2. Materials and Methods

In this study, the materials used were carbon particle from rice plant, fiberglass, Polyester Resin and Aluminum powder. The materials were mixed to produce aluminum and carbon particle reinforced composite. The composition of composite can be seen in table 1.

Table 1. Composition of Composite

| No | Al powder size | Al powder (%) | Fiberglass (%) | Polyester Resin (%) | Rice plant fiber (%) |
|----|----------------|---------------|----------------|---------------------|---------------------|
| 1  | Mesh 40        | 10            | 10             | 40                  | 40                  |
| 2  | Mesh 50        | 10            | 10             | 40                  | 40                  |
| 3  | Mesh 60        | 10            | 10             | 40                  | 40                  |

2.1. Methods

This research was conducted in several stages. The stages that were passed:

1. Prepare tools and materials
2. Calculate the composition of the brake lining materials
3. The materials were weighed using digital scales according to the composition and then manually mixed until the material is evenly mixed.
4. Place a mixture of material in the mold.
5. The next step is to press the mold using a press machine. Pressing was conducted by giving heat at a temperature of 90 °C. Then it is sintered at 180 °C for 15 minutes.
6. After that, micro photo is taken.
7. Hardness is measured using a durometer shore D hardness tester. Like other hardness tests, that durometer shore D hardness measures the depth of indentation in the material made by a force applied to a standard presser foot. This depth depends on the hardness of the material namely the viscoelastic properties, the shape of the presser foot, and the time of testing. These basic tests require the application of a stable force, indentation depth and absence of jerking. For example, the hardness tested has time to apply the force and then read the hardness from the object.
8. Perform friction testing to find the wear value and coefficient of friction. Wear is generally defined as progressive loss of material or the transfer of a number of materials from a surface as a result of
the relative movement between the surface and other surfaces. The explanation of wear mechanisms in the material is closely related to friction and lubrication against external systems (surface contact). Any material can experience wear due to various mechanisms.

3. Results and Discussion
Brake linings made from the composites are shown in figure 1. These aluminum powders are filtered with mesh 40, 50 and 60. The larger the mesh values the smaller the size of aluminum powder.

![Figure 1](image1.png)

**Figure 1.** Brake lining form rice plant composite with aluminum powder produced from filter of mesh 40, 50 and 60.

Figure 2 shows aluminum powder mesh 40 on a rice plant fiber reinforced composite, while figure 3 shows aluminum powder mesh 50 and figure 4 shows aluminum powder mesh 60. Seen in the picture, the size of aluminum gets smaller as the mesh gets bigger.

![Figure 2](image2.png)

**Figure 2.** Micro Photograph of aluminum powder mesh 40.
The test results show a tendency to increase hardness when the size of aluminum powder gets smaller as illustrated in figure 5. Aluminum powder with mesh of 40 produces a hardness of 79.5 HD, mesh of 50 produces hardness of 82.7 HD and mesh of 60 produces hardness of 84.6 HD.
Wear experienced by brake lining shows a declining trend, when the size of aluminum powder is getting smaller, both for dry conditions and conditions with brake oil as shown in figure 6. From aluminum powder size of mesh 40 to 60, the wear decrease from 112.5 mm$^3$/hour to 81.25 mm$^3$/hour in dry condition and from 78.12 mm$^3$/hour to 68.34 mm$^3$/hour in brake oil environment. The figure 6 also shows that when the brake lining works in the brake oil environment, the wear that occurs will decrease compared to when working in dry conditions.

![Figure 6. Relationship between aluminum powder size and wear.](image)

The relationship between the coefficient of friction and the size of aluminum powder is shown in figure 7. The smaller the size of the aluminum powder the greater the coefficient of friction will be. This trend is shown both in dry conditions and conditions with brake oil. However conditions with brake oil show a smaller coefficient of friction than dry conditions. Dry conditions produce a friction coefficient of 0.5799, 0.6017 and 0.6302 for mesh of 40, 50 and 60, respectively. While conditions with brake oil produce a friction coefficient of 0.5568, 0.5738 and 0.5862 for mesh of 40, 50 and 60, respectively.

![Figure 7. Relationship between aluminum powder size and wear.](image)

Adhesive failure is an interfacial bond failure between the adhesive and the adherent. Figure 8 until figure 10 show the bond failure that occurs in the specimen. Adhesive failure was seen in all three specimens that had been tested for wear.
Figure 8. Failure of adhesive bonding in rice plant fiber reinforced composite with aluminum powder mesh of 40.

Figure 9. Failure of adhesive bonding in rice plant fiber reinforced composite with aluminum powder mesh of 50.

Figure 10. Failure of adhesive bonding in rice plant fiber reinforced composite with aluminum powder mesh of 60.
4. Conclusion
From the test results, conclusions can be taken as follows:
1. The smaller the size of the aluminum powder, the harder the rice plant fiber reinforced composite. From aluminum powder size of mesh 40 to 60, the hardness increase from 79.5 HD to 84.6 HD
2. The smaller the size of aluminum powder, the less wear of rice plant fiber reinforced composites. From aluminum powder size of mesh 40 to 60, the wear decrease from 112.5 mm³/hour to 81.25 mm³/hour in dry condition and from 78.12 mm³/hour to 68.34 mm³/hour in brake oil environment.
3. The smaller the size of aluminum powder, the higher coefficient of friction of rice plant fiber reinforced composites. From aluminum powder size of mesh 40 to 60, the coefficient of friction increase from 0.5799 to 0.6302 in dry condition and from 0.5568 to 0.5862 in brake oil environment.
4. The failure of the adhesive is seen in the specimen after being tested for wear.

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