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## The Effect of Aren Palm Fiber Particle Size on Wea

Jihan Pamungkas<sup>1\*</sup>, Arthur Leiwakabessy<sup>2\*</sup>, Cendy S. E. Tupamahu<sup>3</sup>

<sup>1,2,3</sup> Pattimura, University

Email: [Jihanpamungkas@gmail.com](mailto:Jihanpamungkas@gmail.com)

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### Abstract

Brake lining is a critical component in vehicle safety, traditionally made from asbestos-based materials that pose health and environmental risks. To address this, natural fibers such as *Arenga pinnata* (ijuk) have been explored as eco-friendly alternatives due to their durability and resistance to decomposition. This study aims to analyze the effect of ijuk fiber particle size on the wear rate of non-asbestos brake pad composites. The research employed a quantitative experimental method with controlled conditions. The population comprised non-asbestos composites reinforced with ijuk fiber, while the samples were cylindrical specimens (1 cm diameter × 1.5 cm height) fabricated with particle sizes of 40 mesh (400 μm), 50 mesh (300 μm), and 60 mesh (250 μm). Each sample contained 25% ijuk fiber, 10% polyester resin, 45% brass powder, and 20% magnesium oxide, compacted at 2 tons for 20 minutes and sintered at 150°C. Wear testing was conducted using a pin-on-disk tribometer based on ASTM G-99 standards, with 100 RPM rotational speed and 600-second test duration. Each particle size variation was tested five times, and results were analyzed descriptively. Findings revealed that the highest wear rate occurred at 40 mesh ( $1.83 \times 10^{-7}$  g/mm<sup>2</sup>·s), followed by 50 mesh ( $1.36 \times 10^{-7}$  g/mm<sup>2</sup>·s), while the lowest was at 60 mesh ( $8.49 \times 10^{-8}$  g/mm<sup>2</sup>·s). The results indicate an inverse relationship between particle size and wear rate, where finer particles enhance interfacial bonding and reduce material loss. This confirms that smaller particle sizes improve composite performance and durability, making ijuk-based composites a promising alternative for brake lining applications.

**Keywords:** Non-Asbestos Brake Lining, Palm Fiber, Wear Rate, Particle Size

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## INTRODUCTION

Brake pads are essential components of motor vehicles, responsible for slowing down or stopping motion. Their performance is directly tied to vehicle safety, and thus, they must possess excellent physical and mechanical properties, as well as high-quality frictional characteristics (Kumar & Kumaran, 2019). The friction material itself is critical in determining the brake pad's performance, as it directly influences wear resistance, noise reduction, and overall mechanical strength. Traditionally, asbestos-based materials were widely used for this purpose due to their exceptional thermal resistance (Primaningtyas et al., 2018; U.S. Environmental Protection Agency, 2024). However, the use of asbestos is now prohibited in many countries due to its severe health risks and environmental hazards (Zain, 2023). This has driven extensive research into developing safer, more sustainable alternatives.

In recent years, researchers have focused on developing environmentally friendly, non-asbestos organic (NAO) brake pads using natural fibers as a reinforcing material (Lusiani & Purnama, 2016; Ramadhan, 2015). Various natural fibers, such as those from palm fronds, bamboo, corn cobs, coconut shells, and teak wood, have been investigated for this application, showing promising results in improving the mechanical properties and wear resistance of brake pads (Yudhanto et al., 2019). Among these natural fibers, *Arenga pinnata* fiber, known as *ijuk* in Indonesian, stands out as a particularly promising reinforcement material (Samlawi et al., n.d.). *Ijuk* fiber possesses unique properties, including high durability, excellent resistance to decomposition, and strong resistance to acids and salts (Teke, 2021). Its chemical composition, which includes 52.3% cellulose, 13.3% hemicellulose, and 31.5% lignin, makes it a viable candidate for friction material applications (Teke, 2021).

In addition to the type of fiber, particle size plays a crucial role in the physical and mechanical properties of composite materials. Larger particles tend to create rougher surfaces and weaker inter-particle bonds, leading to increased porosity and poor bonding with the matrix (Ariawan & Wr, 2010; El-Sayed et al., 2023). Conversely, smaller particles result in a smoother surface and stronger bonds due to better distribution and enhanced interaction with the matrix material (Ariawan & Wr, 2010). Previous studies on the effect of particle size on brake pads have shown that smaller particles improve compressive strength, reduce porosity, and decrease mass loss and wear rates (Nandiyanto et al., 2021; Jember University et al., 2017). Specifically, research on rice husk and coconut shell powder has demonstrated that finer particle sizes lead to a more even dispersion within the composite, which in turn improves hardness and reduces wear rates (Nandiyanto et al., 2021; Jember University et al., 2017).

This research aims to investigate the influence of *ijuk* fiber particle size on the wear rate of brake pad composites. The study seeks to determine which particle size variation yields the lowest wear rate, thereby contributing to the development of more durable and effective non-asbestos brake pads. The urgency of this research lies in the critical need to find sustainable, safe, and high-performance alternatives to traditional asbestos-based friction materials. This study's novelty is in its specific focus on the effect of varying *ijuk* fiber particle sizes on brake pad performance, a topic that has not been extensively explored in the existing literature, particularly with a specific focus on different mesh sizes (40  $\mu\text{m}$ , 50  $\mu\text{m}$ , and 60  $\mu\text{m}$ ). The findings will provide valuable insights for optimizing the composition of eco-friendly brake pad materials.

## RESEARCH METHODS

### Research Type and Method

This study employs a quantitative approach with an experimental method to investigate the effect of *ijuk* fiber particle size on the wear rate of non-asbestos brake pad composites (Nandiyanto et al., 2021; Emzir, 2017). This method is suitable for a cause-and-effect relationship, allowing for the manipulation of the independent variable—particle size—to observe its impact on the dependent variable, which is the wear rate of the composite material (Sudaryono, 2017). The experimental design allows for controlled conditions to ensure the validity and reliability of the data. This research was conducted at SMK Negeri 3 Ambon for sample preparation and at the CAD/CAM Laboratory of Pattimura University for the wear rate testing.

### Population and Sample

The population of this study comprises non-asbestos composite materials reinforced with *ijuk* fiber. The samples were specifically prepared in a cylindrical shape with a diameter of 1 cm and a height of 1.5 cm. Three variations of *ijuk* fiber particle sizes were used as the primary variable for the experiment: 400  $\mu\text{m}$  (40 mesh), 300  $\mu\text{m}$  (50 mesh), and 250  $\mu\text{m}$  (60 mesh). This selection of sample sizes and particle variations allows for a detailed analysis of how particle fineness influences the material's tribological properties (Jember University et al., 2017; Syaputra, 2017).

The material composition for all samples was kept consistent to isolate the effect of particle size. The composite consisted of 25% *ijuk* fiber, 10% polyester resin (Yukalac BQTN 157 with Hardener catalyst), 45% brass powder, and 20% magnesium oxide. The samples were compacted at a pressure of 2 tons for 20 minutes using a hydraulic press to ensure consistent density and structural integrity across all specimens (Prasetyo et al., n.d.; Sugiyono, 2017).

### Research Procedures

The experimental procedure was conducted in several stages: specimen preparation, composite fabrication, and wear rate testing. First, the molds and supporting equipment were prepared and cleaned. The *ijuk* fibers were then sieved using sieves with mesh sizes of 40, 50, and 60 to obtain the specified uniform particle sizes. The raw materials were then weighed and mixed thoroughly in a container to create a homogeneous mixture. The mixture was then carefully placed into the molds, which were coated with a release agent to facilitate easy removal of the specimens after compaction.

Next, the mixture was cold-pressed using a hydraulic press machine at 2 tons of pressure for 20 minutes. After compaction, the green specimens were removed from the molds and subjected to a sintering process in a heating oven at 150°C for 15 minutes. This heat treatment was performed to enhance the bonding and mechanical strength of the composite (Ardiyan, n.d.). Finally, the specimens were cooled to room temperature and polished with sandpaper (P600) to achieve a smooth surface finish before testing.

### Instruments and Data Analysis Techniques

The wear rate testing was performed using a pin-on-disk tribometer by the ASTM G-99 standard (Ramadhan, 2015). This instrument is ideal for measuring the frictional and wear properties of materials by simulating a sliding contact between a stationary pin and a rotating disk (Yudhanto et al., 2019). The test was performed with a rotational speed of 100 RPM and a test duration of 600 seconds for each specimen. To ensure the accuracy and reliability of the data, the test was repeated five times for each of the three particle size variations (Sugiyono, 2017). The wear rate was calculated based on the weight loss of the samples before and after the test, using Equation (1):

$$\text{WearRate} = \frac{A \cdot (W_i - W_f)}{t}$$

where  $W_i$  is the initial weight,  $W_f$  is the final weight,  $A$  is the contact area, and  $t$  is the test duration. The data were then analyzed using a descriptive statistical approach to determine the average wear rate for each particle size and compare the results to draw conclusions.

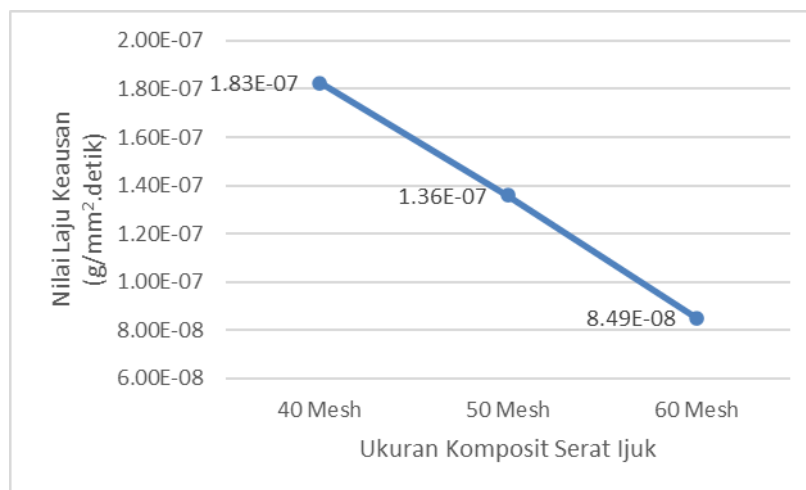
## RESULTS AND DISCUSSION

### Wear Rate Test Results

The friction coefficient test was conducted using a pin-on-disk tribometer, according to the ASTM G-99 standard. The specimens were tested five times for each of the three mesh size variations of the brake pad composite. The test parameters were a rotational speed of 100 RPM and a duration of 600 seconds. The data obtained from the wear test is presented in the following table.

**Table 1. Wear Rate Test Data**

N o	Specimen t	Wear Rate Sample 1	Wear Rate Sample 2	Wear Rate Sample 3	Wear Rate Sampel 4	Wear Rate Sample 5	Average Wear Rate
1	Mesh 40	$1,91 \times 10^{-7}$	$1,70 \times 10^{-7}$	$1,70 \times 10^{-7}$	$1,91 \times 10^{-7}$	$1,91 \times 10^{-7}$	$1,83 \times 10^{-7}$
2	Mesh 50	$1,49 \times 10^{-7}$	$1,27 \times 10^{-7}$	$1,49 \times 10^{-7}$	$1,27 \times 10^{-7}$	$1,27 \times 10^{-7}$	$1,36 \times 10^{-7}$
3	Mesh 60	$1,06 \times 10^{-7}$	$8,49 \times 10^{-8}$	$6,37 \times 10^{-8}$	$8,49 \times 10^{-8}$	$8,49 \times 10^{-8}$	$8,49 \times 10^{-8}$



**Picture 1. Wear Rate Value Graph**

The results, as depicted in the graph below, clearly indicate a relationship between particle size and the wear rate of the brake pad composites. The specimen with the 40 mesh *ijuk* particles exhibited the highest average wear rate at  $1.83 \times 10^{-7} \text{ g/mm}^2 \cdot \text{s}$ . In contrast, the 50 mesh specimens showed a lower wear rate of  $1.36 \times 10^{-7} \text{ g/mm}^2 \cdot \text{s}$ , and the 60 mesh specimens recorded the lowest wear rate at  $8.49 \times 10^{-8} \text{ g/mm}^2 \cdot \text{s}$ . This trend demonstrates that smaller particle sizes result in a lower wear rate.

This finding aligns with the fundamental principles of composite material science. A smaller particle size provides a larger surface area-to-volume ratio, which enhances the

interfacial bonding between the *ijuk* particles and the polyester resin matrix. The increased surface area allows for a more extensive and robust chemical and mechanical interlocking between the reinforcing fibers and the matrix. This improved bonding leads to a stronger, more cohesive composite structure, effectively reducing the detachment of particles during abrasive and adhesive wear mechanisms. Conversely, larger particles create a less uniform distribution within the matrix, leading to weak points and porosity, which can act as stress concentrators and accelerate material loss under friction. Therefore, the specimen with the finest particles (60 mesh) showed superior wear resistance, making it the most suitable variation for this application.

## CONCLUSION

Based on the results and analysis of this study, it can be concluded that the particle size of *ijuk* fiber is a significant factor influencing the wear rate of non-asbestos brake pad composites. The research clearly shows an inverse relationship: as particle size decreases, the wear rate also decreases. Specifically, the specimens with 60 mesh particles exhibited the lowest wear rate ( $8.49 \times 10^{-8}$  g/mm<sup>2</sup>·s), while the 40 mesh particles had the highest wear rate ( $1.83 \times 10^{-7}$  g/mm<sup>2</sup>·s). This finding confirms that the larger surface area of finer particles enhances the interfacial bonding between the *ijuk* fibers and the polyester resin matrix, resulting in a stronger and more cohesive composite structure that improves wear resistance. While these findings are promising, the study has certain limitations, as it focused exclusively on the wear rate. For a comprehensive brake pad evaluation, future research should investigate the effect of particle size on other critical tribological properties, such as the coefficient of friction and thermal stability (fade resistance). Additionally, further exploration of other mechanical properties like compressive strength and hardness, along with variations in the material composition, would provide a more holistic understanding of the *ijuk*-based composite's potential as a viable and eco-friendly alternative.

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