

The Effect of Adding Teak Wood Powder to Brake Pad Composites on Wear and Impact Toughness

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Abstract

Using teak wood powder as a brake pad reinforcement has potential for development because it can produce wear values that meet the standards. Research that combines teak wood powder with two types of fillers, namely brass powder and magnesium oxide, has not been widely conducted yet. This study aims to utilize teak wood sawdust waste as the primary reinforcing material in non-asbestos epoxy-matrix brake pad composites and to analyze the effect of composition variations on the mechanical properties of the composites. An experimental method was employed using variations in the composition of teak wood sawdust, brass powder, magnesium oxide, and epoxy resin, namely variation one 20%:20%:20%:40%, variation two 30%:15%:15%:40%, and variation three 40%:10%:10%:40%. The fabrication process included mechanical mixing, compaction under a pressure of 5 tons for 30 minutes, and sintering at a temperature of 150°C for 30 minutes. The testing consisted of an ogoshi wear test using commercial motorcycle brake pads as a comparison and a charpy impact test. The wear test results showed the highest wear value in variation one at $8.21 \times 10^{-7} \text{ mm}^2/\text{kg}$ and the lowest in variation three at $4.59 \times 10^{-7} \text{ mm}^2/\text{kg}$, which is lower than that of the commercial brake pad at $6.748 \times 10^{-7} \text{ mm}^2/\text{kg}$. The charpy impact test results indicated that the impact toughness of the composites tended to increase with increasing teak wood sawdust fraction, with the highest value obtained in variation three at 0.082 J/mm^2 and an absorbed energy of 5.150 J . Therefore, variations in teak wood sawdust composition significantly affect the mechanical properties of non-asbestos brake pad composites.

Keywords: brake pads; composite; non-asbestos; teak wood powder; mechanical properties

Abstrak

Pemanfaatan serbuk kayu jati sebagai penguat kampas rem memiliki potensi untuk dikembangkan karena bisa menghasilkan nilai keausan yang memenuhi standar. Penelitian yang mengombinasikan serbuk kayu jati dengan dua jenis bahan pengisi berupa serbuk kuningan dan magnesium oksida masih belum banyak dilakukan. Penelitian ini bertujuan memanfaatkan limbah serbuk kayu jati sebagai bahan penguat utama pada komposit kampas rem non-asbestos bermatriks epoksi serta menganalisis pengaruh variasi komposisi terhadap sifat mekanik komposit. Metode eksperimental dilakukan dengan variasi komposisi serbuk kayu jati, serbuk kuningan, magnesium oksida, dan resin epoksi, yaitu variasi satu 20%:20%:20%:40%, variasi dua 30%:15%:15%:40%, dan variasi tiga 40%:10%:10%:40%. Proses pembuatan meliputi pencampuran mekanis, kompaksi dengan tekanan 5 ton selama 30 menit, serta sintering pada suhu 150°C selama 30 menit. Pengujian dilakukan uji keausan metode *ogoshi* dengan kampas rem sepeda motor komersial sebagai pembanding dan uji impak metode *charpy*. Hasil uji keausan menunjukkan nilai tertinggi pada variasi satu sebesar $8,21 \times 10^{-7} \text{ mm}^2/\text{kg}$ dan terendah pada variasi tiga sebesar $4,59 \times 10^{-7} \text{ mm}^2/\text{kg}$, yang lebih rendah dibandingkan kampas rem komersial sebesar $6,748 \times 10^{-7} \text{ mm}^2/\text{kg}$. Hasil uji impak metode *charpy* menunjukkan bahwa nilai ketangguhan impak komposit cenderung meningkat seiring bertambahnya fraksi serbuk kayu jati, dengan nilai tertinggi pada variasi tiga sebesar $0,082 \text{ J/mm}^2$ dan energi serap sebesar $5,150 \text{ J}$. Dengan demikian, variasi komposisi serbuk kayu jati memberikan pengaruh terhadap sifat mekanik komposit kampas rem non-asbestos.

Kata kunci: kampas rem; komposit; non-asbestos; serbuk kayu jati; sifat mekanik

1. Introduction

The automotive industry in Indonesia has experienced rapid development. This condition demands continuous innovation in developing systems that can enhance comfort, efficiency, safety, and driving security, particularly in braking systems. The Central Bureau of Statistics (BPS) recorded that the number of motorcycles in Indonesia reached 126,993,797 units in 2022 [1]. The increase in the number of vehicles has resulted in a growing demand for components that frequently require replacement, namely brake pads. The braking system on motorcycles is a vital component because

it functions to slow down and stop the vehicle by converting kinetic energy into heat energy. The disc brake system operates hydraulically, where brake fluid transmits pressure from the lever to the caliper piston, causing the brake pads to clamp the rotating stainless-steel disc and generate friction to slow or stop the wheel rotation [2]. Therefore, brake components must have material properties that are resistant to friction and do not generate excessive heat that could cause the material to melt or deform. Some of these materials include copper, brass, lead, graphite, carbon, Kevlar, resin, fiber, and other additive materials [3].

Along with the increasing demand for brake pad materials, it is necessary to develop alternative materials that possess mechanical characteristics suitable for braking applications. In this regard, the utilization of teak wood dust waste produced by the wood processing industry presents a potential area for research. Teak wood dust waste is generated in relatively large quantities, approximately 10.6% from each sawing process, but until now, most of it has not been optimally utilized [4]. The high demand for teak wood as a construction and furniture material encourages the growth of large-scale sawmill industries as well as small and medium enterprises (SMEs), resulting in an increasing amount of teak wood dust waste. This condition opens opportunities for utilizing teak wood dust as a reinforcing material in composite materials for automotive components, particularly non-asbestos brake pads. Non-asbestos brake pads are brake pads that do not use asbestos as a constituent material. Brake pad composites made from teak wood dust, brass powder, and epoxy matrix have been found to produce wear values close to commercial brake pads, indicating potential for further development as an alternative brake pad material [5].

Teak wood (*Tectona grandis* L. f.) is a type of wood with potential use as a reinforcement material for non-asbestos brake pad composites due to its strength, durability, ease of processing, and density suitable for fiber substitution. Brass powder can serve as a filler material because it has good thermal conductivity, helping to dissipate heat on the brake pad surface, is ductile, and corrosion-resistant [6]. Magnesium oxide (MgO) is used as an additional filler and abrasive material due to its low density, high melting point, and good mechanical strength. The abrasive properties and high thermal resistance of MgO play an important role in improving composite wear resistance and maintaining friction coefficient stability at high temperatures [7]. The matrix used is epoxy resin, which possesses excellent mechanical properties, high thermal resistance, water resistance, low shrinkage, good dimensional stability, and can withstand temperatures up to 220°C [8].

Several studies have investigated the use of natural and metallic fillers in composite brake pad materials to improve their mechanical and wear properties. Alamsyah and Gundara reported that increasing the fraction of teak wood dust in epoxy-based composites reduced the wear rate, with the lowest value of 2.2×10^{-4} mm²/kg observed in the composition containing 30% teak wood dust, 30% brass powder, and 40% epoxy resin [6]. Similarly, Rachmada found that a lower proportion of water hyacinth fiber (10%) produced better wear resistance compared to higher fiber fractions [9]. Pramono showed that post-curing treatment at 180°C significantly improved the wear resistance of teak wood dust–coconut shell–brass composites, achieving a specific wear value close to that of standard commercial brake pads [5]. Additionally, Purboputro and Prabowo demonstrated that brass powder with a finer mesh size (60 mesh) improved the friction and wear performance of fiber–polyester composites under various conditions [10]. Other researchers have explored the use of teak wood–based materials to enhance composite performance. Shibghaturrahman reported that teak wood powder subjected to pyrolysis and mixed in a 40:60 ratio with epoxy resin exhibited the lowest wear value of 0.00232 mm³/kg·m, indicating good wear resistance [11]. Handoko found that a composition of 20% teak wood dust and 80% epoxy resin produced the highest impact energy absorption of 4.30 J, while higher filler contents reduced impact toughness due to increased brittleness and void formation [12]. In addition, Arif showed that teak wood sawdust composites with a 60:40 ratio of

filler to epoxy resin achieved the highest tensile strength of 16 MPa [13]. These findings collectively indicate that optimizing the ratio of natural filler and epoxy matrix is crucial for achieving superior mechanical and wear properties.

Based on the above description, the utilization of teak wood dust as a reinforcement material for brake pad composites has been explored in several previous studies. However, studies that combine teak wood dust with two types of filler materials, namely brass powder and magnesium oxide, in an epoxy matrix composite are still limited. In addition, the effect of varying material compositions on wear resistance and impact toughness has not been analyzed comprehensively. Therefore, this study aims to investigate the influence of variations in the composition of teak wood dust, brass powder, magnesium oxide, and epoxy resin on the mechanical properties of brake pad composites. Through this approach, it is expected that the study can provide a clearer understanding of the relationship between composition and performance to obtain an optimal brake pad material that meets mechanical and safety standards.

2. Material and Method

2.1. Materials

The materials used in this study include several key components that play specific roles in the fabrication of the composite specimens. The primary reinforcement material is teak wood dust, which provides structural strength and acts as a natural fiber element within the composite. As a metallic filler brass powder is incorporated to enhance thermal conductivity and wear resistance, while magnesium oxide serves as an additional filler that contributes to the abrasive and thermal stability characteristics of the material. The binding agent consists of epoxy resin and hardener, which together form the matrix that holds all components in place, ensuring mechanical integrity and durability. Figure 1 shows the materials that used in this research.



Figure 1. Raw materials used for composite fabrication (a) Teak wood powder; (b) Brass powder; (c) Magnesium oxide; (d) epoxy resin and hardener

The teak wood dust is utilized without the carbonization process, and different particle sizes are applied for each material, with a mesh size of 40 for teak wood dust, 60 for brass powder, and particle size pass 150 for magnesium oxide.

The materials are then mixed using a mixer and mixing container to ensure homogeneous dispersion, followed by compaction with a hydraulic press to form solid specimens of the desired dimensions. The sintering process is conducted using an electric oven to strengthen particle bonding.

2.2. Methods

The composite is made in three composition variations, which are 20 percent teak wood dust, 20 percent brass powder, 20 percent magnesium oxide, and 40 percent epoxy resin for the first variation, 30 percent teak wood dust, 15 percent brass powder, 15 percent magnesium oxide, and 40 percent epoxy resin for the second variation, and 40 percent teak wood dust, 10 percent brass powder, 10 percent magnesium oxide, and 40 percent epoxy resin for the third variation. The materials are mixed using a mixer operating at a speed of 800 to 900 revolutions per minute for two minutes, followed by compaction under a pressure of five tons for thirty minutes and sintering at a temperature of 150°C for thirty minutes.

This study employs an experimental research method in which direct testing is conducted to analyze the effect of teak wood dust composition variations on the mechanical properties of epoxy matrix composites used for brake pad materials. The testing methods consist of two primary mechanical evaluations: the wear test, performed using the Ogoshi method in accordance with the ASTM G99-95a standard, and the impact test, performed using the Charpy method based on the ASTM D6110 standard.



Figure 2. Experimental testing machine (a) Ogoshi wear testing machine type OAT-U, (b) Charpy impact testing machine

3. Results and Discussion

3.1. Wear Test Results

The wear test using the Ogoshi method was conducted at the Laboratory of Engineering Materials, Faculty of Mechanical and Industrial Engineering, Universitas Gadjah Mada, Yogyakarta. The test was performed under a normal load of 6.36 kg, with an abrasive disc thickness of 3 mm and a disc radius of 13 mm, and a sliding distance of 15 m. The test specimens had dimensions of 50 × 30 × 5 mm, and three specimens were tested for each condition. The wear scar width was measured at five different points on each specimen, and the final wear value was obtained by averaging the five measurements. The average wear width on the variation 1 specimen is 1.3952 mm, resulting in a specific wear value of $8.21 \times 10^{-7} \text{ mm}^2/\text{kg}$, as shown in figure 3(a). The average wear width on the variation 2 specimen is 1.1784 mm, resulting in a specific wear value of $4.95 \times 10^{-7} \text{ mm}^2/\text{kg}$, as shown in figure 3(b). The average wear width on the variation 3 specimen is 1.1498 mm, resulting in a specific wear value of $4.59 \times 10^{-7} \text{ mm}^2/\text{kg}$, as shown in figure 3(c).

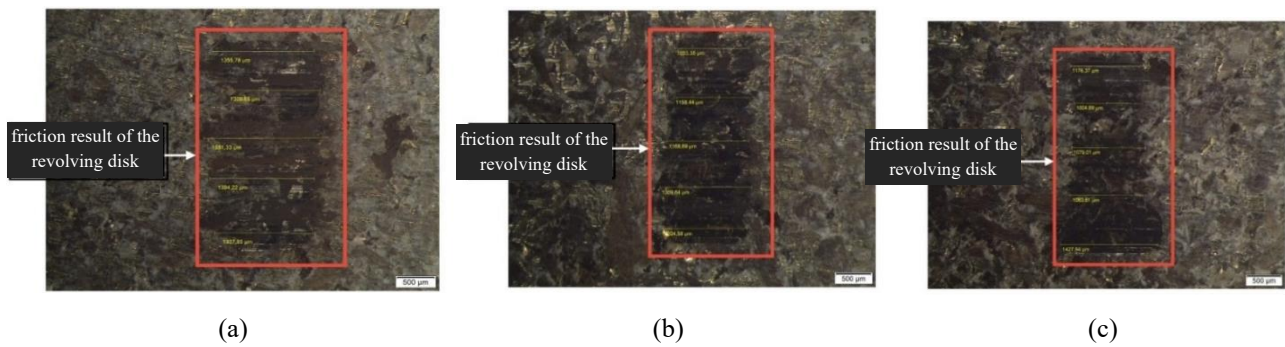


Figure 3. Wear test result (a) variation 1, (b) variation 2, (c) variation 3

The wear rates obtained from each variation are shown in figure 4.

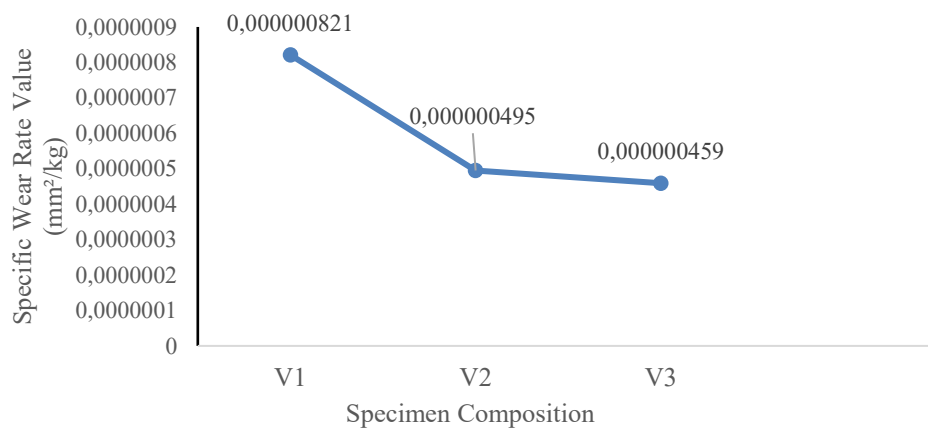


Figure 4. Wear test results graph

Based on the results shown in Figure 4, each variation of teak wood dust composition produced different specific wear values. Variation 1 exhibited the highest specific wear value of $8.21 \times 10^{-7} \text{ mm}^2/\text{kg}$, indicating lower wear resistance. This suggests that at a lower teak wood dust content, the filler's ability to reinforce the epoxy matrix composite is still suboptimal, leading to greater particle detachment and surface degradation during friction testing. A significant reduction in specific wear was observed in variation 2, with a value of $4.95 \times 10^{-7} \text{ mm}^2/\text{kg}$. The increase in teak wood dust content enhanced filler distribution, providing better resistance to frictional wear. However, some inconsistencies in mixing and compaction may have prevented this composition from reaching maximum performance. The best wear resistance was achieved by variation 3, which recorded the lowest specific wear value of $4.59 \times 10^{-7} \text{ mm}^2/\text{kg}$. The higher amount of teak wood dust contributed to a denser and stronger composite structure, effectively reducing particle removal and surface damage. The compact filler network improved surface stability, resulting in superior wear resistance.

For comparison, previous research by Fuad and Yudiono using the ogoshi method reported a specific wear value of $6.748 \times 10^{-7} \text{ mm}^2/\text{kg}$ for commercial motorcycle brake pads. When compared to this benchmark, variation 1 showed lower wear resistance than commercial materials, while variations 2 and 3 achieved better performance, producing lower specific wear values [14]. This improvement is attributed to better filler distribution, mixing uniformity, and compaction density during specimen fabrication. Overall, variation 3 (SJ 40% : SK 10% : MO 10% : RE 40%) demonstrated the most optimal composition, yielding the lowest wear rate and surpassing the performance of the commercial reference material.

3.2. Impact Test Results

The test utilized a charpy impact testing machine with a pendulum mass (m) of 34.15 kg, arm length (R) of 0.80 m, initial pendulum angle (α) of 150° , and gravitational acceleration (g) of 9.81 m/s^2 .

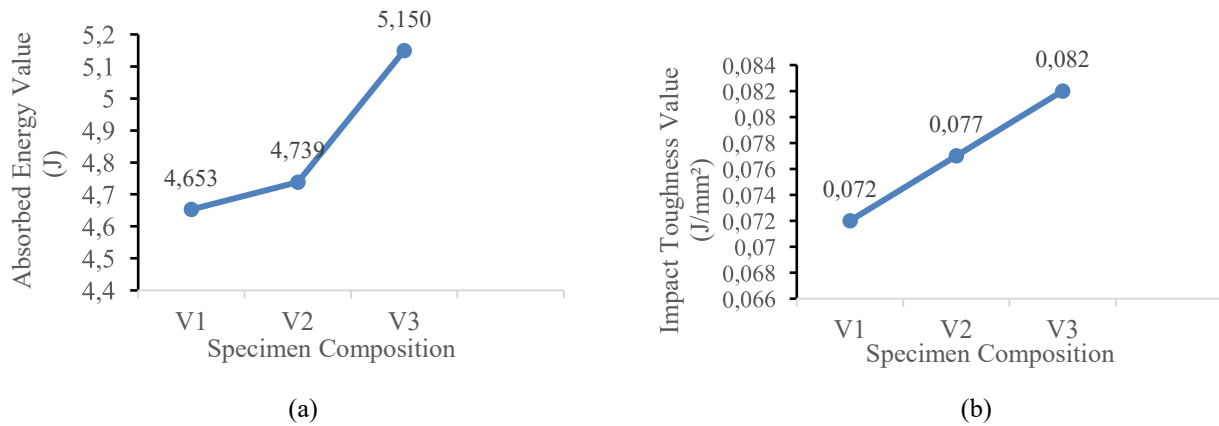


Figure 5. Impact test results (a) Absorbed energy results graph; (b) Impact toughness results graph

The swing angle after impact (β) was recorded to determine the absorbed energy (E_{srp}) of the specimen during impact. This energy value was then used to calculate the impact toughness (HI) of the composite material. Testing was performed on impact test specimens with three repetitions. The test data were then used to determine the absorption energy and impact toughness of the composite, as shown in Figure 5.

Based on the experimental results, variations in the composition of teak wood dust, brass powder, and magnesium oxide significantly influenced the composite's ability to absorb impact energy. Variation 1 exhibited the lowest impact performance, with an average absorbed energy of 4.653 J and an impact toughness of 0.072 J/mm^2 . This occurred due to the dominance of hard and brittle inorganic fillers on brass and magnesium oxide each present at 20%. These hard particles tend to initiate cracks easily, leading to brittle fracture and poor energy dissipation, which ultimately reduced the composite's overall toughness. In variation 2, the absorbed energy increased to 4.739 J, while the impact toughness improved to 0.077 J/mm^2 . The addition of teak wood dust up to 30% enhanced the composite's flexibility and energy absorption capacity by reducing the dominance of hard filler particles. The natural fiber characteristics of teak wood dust helped redistribute impact stress and delayed the onset of cracking, resulting in better impact resistance compared to the previous variation. The best mechanical performance was achieved by variation 3, which recorded the highest absorbed energy of 5.150 J and the highest impact toughness of 0.082 J/mm^2 . The greater proportion of teak wood dust improved the composite's ability to absorb and dissipate impact energy more evenly. At the same time, the reduced amounts of brass powder and magnesium oxide minimized brittleness, allowing the composite to deform slightly before failure.

Overall, increasing the content of teak wood dust proved effective in improving the composite's energy absorption and impact resistance. The natural fibers distributed stress more uniformly and delayed crack propagation, thereby enhancing toughness. This observation is consistent with findings by Wibawa, who reported that a higher teak wood dust fraction contributes to increased impact strength in epoxy-based composites. Consequently, the composition of 40% teak wood dust, 10% brass powder, 10% magnesium oxide, and 40% epoxy resin is identified as the most optimal for brake pad applications due to its superior impact performance [15].

4. Conclusion

Based on the research conducted, it can be concluded that the variation in teak wood dust composition significantly influences the mechanical properties of epoxy matrix composites used for brake pad materials. The ogoshi wear test results showed that increasing the teak wood dust fraction led to a decrease in the wear rate of the composite. The higher amount of teak wood dust contributed to a denser and stronger composite structure, effectively reducing particle removal and surface damage. The compact filler network improved surface stability, resulting in superior wear resistance compared to the other variations. The highest wear value was recorded in variation 1 at $8.21 \times 10^{-7} \text{ mm}^2/\text{kg}$. When compared to a commercial brake pad with a wear value of $6.748 \times 10^{-7} \text{ mm}^2/\text{kg}$, variation 3 demonstrated superior wear resistance, making it the most optimal composition based on wear performance.

The charpy impact test results further revealed that a higher teak wood dust fraction improved the impact toughness of the composite. The greater proportion of teak wood dust improved the composite's ability to absorb and dissipate impact energy more evenly. The impact toughness increased progressively from 0.072 J/mm^2 in variation 1 to 0.082 J/mm^2 in variation 3. This enhancement in impact resistance indicates that teak wood dust contributes to better energy absorption and crack resistance within the composite structure. Therefore, among the tested variations, variation 3 exhibited the best balance between strength and toughness, confirming it as the most effective composition for improving the mechanical performance of epoxy-based brake pad materials.

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