The Effect of Teak Wood, Mahogany Wood, And Brass Powder Composite Variations as Alternative Materials for Brake Pads on Hardness and Bending Tests

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**Abstract.** The automotive industry’s growth demands eco-friendly materials, including brake pad components. This study investigates the effect of composite variations of teak wood powder, mahogany wood powder, and brass powder as alternative materials for brake pads on hardness and bending properties. Addressing the need for sustainable and safer materials, the research employs epoxy resin as a matrix with composite compositions of 60%, 55%, and 50% wood and brass powders. The brake pad fabrication process involves pressing and sintering at 300 degrees C for 10 minutes. Hardness testing follows the Brinell method, while bending tests adhere to ASTM D790 to evaluate flexural strength. The results demonstrate the optimal composition for enhancing hardness and bending resistance, contributing to environmentally friendly brake pad development. This study offers a potential asbestos-free alternative for the automotive industry.

# INTRODUCTION

The automotive industry, particularly in motorcycle component production, faces intense competition among manufacturers [1]. Brake pads, as frequently replaced components, no longer use asbestos due to its health and environmental risks [2]. Technological advancements and evolving consumer demands necessitate adaptive production processes to meet performance and safety requirements [3]. The braking system functions by converting kinetic energy into heat through friction [4]. If this system fails, accident risks increase, underscoring the need for reliable brake materials. Manufacturers prioritize brake pad materials that ensure safety and performance [5,6].

Wood waste powder, as a natural abrasive, enhances brake pad hardness [7,8]. Teak wood powder, derived from sawing processes, exhibits porous and hygroscopic properties, improving friction performance, reducing wear, and extending component lifespan [9]. Similarly, mahogany wood powder offers high compressive strength, heat absorption, and resistance to repeated friction. Brass, a copper-zinc alloy, is used in brake pads for its strength, low thermal conductivity, friction stability, and wear resistance [10,11]. Previous studies indicate that brass additives improve thermal properties (e.g., conductivity, specific heat capacity) and enhance friction performance under high temperatures [12].

Prior research analyzed the effect of water hyacinth fiber composites with Cu-Zn and MgO fillers on brake pad wear and hardness as an eco-friendly alternative [13]. The highest hardness and lowest wear occurred at 10% hyacinth fiber, while 25% fiber yielded inferior results. Another study by Prasetyo examined sugarcane bagasse and iron powder-reinforced epoxy brake pads, finding optimal hardness (72.5 HD) and wear resistance (0.000203 Wsmm³/kg.m) at 35% bagasse, 15% iron, and 50% epoxy [14,15,5]. These findings highlight the influence of natural material compositions on brake pad performance [16–18].

This study addresses the effect of teak wood, mahogany, and brass powder compositions on brake pad hardness and bending properties. The primary challenge lies in determining the optimal composition to balance mechanical performance and environmental sustainability. By testing varying compositions (60%, 55%, 50%), the research aims to identify the most effective formulation. The results will contribute to developing high-quality, eco-friendly brake pads, offering a viable alternative to asbestos.

# Methodology

This experimental study measures the hardness and bending properties of brake pads fabricated from teak wood, mahogany, and brass powder composites with epoxy resin. Literature reviews support the experimental framework, ensuring relevance to current research trends in sustainable materials.

## Research Location and Tools

Data collection was conducted at two laboratories: (1) the Mechanical Engineering Laboratory of Universitas Muhammadiyah Malang for specimen fabrication and Brinell hardness testing, and (2) the Politeknik Negeri Malang Laboratory for bending tests. These facilities were selected to ensure precision and adherence to testing standards.

Tools included a digital scale (for accurate material measurement), a hydraulic press (for uniform compaction), an electric oven (for sintering at 300°C), and molds (for specimen shaping). Materials comprised teak/mahogany wood powder, brass (Cu-Zn) powder, epoxy resin, and hardener. Wood powders were sourced from sawing waste, while brass powder was obtained from machining waste.

## Specimen Preparation and Testing

Specimens were fabricated via powder metallurgy, following SNI 09-0143-1987 and ASTM D790 (dimensions: 150 × 12.7 × 9 mm). Wood and brass powders were mixed with epoxy resin (1% hardener), pressed at 200 kg for 10 minutes, and sintered at 300°C for 20 minutes.

Hardness testing used a Brinell hardness tester (500 kgf load, 15-second dwell time), with indentation diameters measured via caliper. Bending tests employed a universal testing machine, with load applied incrementally until fracture. Data were recorded for analysis.

# Results and Discussion

## Data and Result Interpretation

Table 1 presents the Brinell Hardness Number (BHN) test results for composite materials containing varying percentages of mahogany wood powder (50%, 55%, and 60%) combined with brass powder and epoxy resin. Each variation was tested using three specimens to ensure consistency and reliability of the data. The average hardness for the 50% mahogany composition was 105.95 kg/mm², which was the highest among the three variations. The 55% composition yielded a slightly lower average of 99.18 kg/mm², while the 60% composition had the lowest average hardness of 92.33 kg/mm². This trend indicates that increasing the proportion of mahogany powder beyond 50% tends to reduce the hardness of the composite. The decrease in BHN values is likely due to the higher volume of wood filler weakening the overall matrix structure, as the wood particles are less rigid compared to brass and resin components.

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| **TABLE 1.** Average Brinell Hardness Test Results for Mahogany Wood Powder. | | | |
| **Variation** | **Number of Specimens** | **Average BHN** | **Average Test Result** |
| Mahogany 50% | 1 | 100.9 |  |
|  | 2 | 107.39 | 105.95 kg/mm² |
|  | 3 | 110.38 |  |
| Mahogany 55% | 1 | 97.66 |  |
|  | 2 | 94.62 | 99.18 kg/mm² |
|  | 3 | 105.27 |  |
| Mahogany 60% | 1 | 79.19 |  |
|  | 2 | 90.29 | 92.33 kg/mm² |
|  | 3 | 105.57 |  |

Similarly, Table 2 shows the BHN results for composites made with teak wood powder in the same percentage variations. The test results reveal a different trend compared to the mahogany-based composites. The average hardness values increased with the teak content: 115.23 kg/mm² for 50%, 123.85 kg/mm² for 55%, and peaking at 125.13 kg/mm² for the 60% composition. This suggests that teak powder contributes more effectively to hardness enhancement than mahogany, potentially due to its denser, tougher fiber structure and better interfacial bonding with the epoxy matrix. All three variations of the teak composite surpassed the typical hardness standards for brake pad applications, indicating their suitability for mechanical applications requiring high surface resistance.

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| **TABLE 2.** Average Brinell Hardness Test Results for Teak Wood Powder. | | | |
| **Variation** | **Number of Specimens** | **Average BHN** | **Average Test Result** |
| Teak 50% | 1 | 116.59 |  |
|  | 2 | 116.83 | 115.23 kg/mm² |
|  | 3 | 112.28 |  |
| Teak 55% | 1 | 130.06 |  |
|  | 2 | 123.70 | 123.85 kg/mm² |
|  | 3 | 117.79 |  |
| Teak 60% | 1 | 120.95 |  |
|  | 2 | 128.72 | 125.13 kg/mm² |
|  | 3 | 125.72 |  |

## Discussion of Mahogany Wood Powder Hardness Test

Testing was conducted with three composition variations—50%, 55%, and 60%—yielding different hardness levels. The process was carried out at a constant temperature of 300°C, as higher sintering temperatures typically enhance material hardness. As shown in Table 1, the 50% mahogany composition achieved the highest Brinell Hardness Number (BHN) of 105.95 kg/mm², followed by 99.18 kg/mm² at 55%, and the lowest at 92.33 kg/mm² for the 60% composition. These results demonstrate the significant impact of composition variation and thermal conditions on material hardness.

**Figure 1.** Design and Components of the 5-Ton/Hour Capacity Conveyor Machine

The graph in Fig. 1 confirms that the 50% composition produces the highest hardness, while the 60% composition results in the lowest. According to N. Iman and D. Widjanarko, the standard brake pad material hardness ranges from 68 to 105 BHN. Hence, the 50% and 55% mahogany-based specimens fall within the standard. The composition of 50% mahogany, 30% brass powder, and 20% epoxy resin yields optimal hardness. Increasing the wood powder to 60% leads to reduced hardness, though still within tolerable limits.

## Discussion of Teak Wood Powder Hardness Test

Testing teak wood powder with the same 50%, 55%, and 60% variations and at 300°C showed that the 60% composition had the highest hardness of 125.13 kg/mm², compared to 115.23 kg/mm² and 123.85 kg/mm² for the 50% and 55% compositions, respectively. Figure 2 illustrates these findings.

**Figure 2.** Influence of Teak Composite Percentage on Brinell Hardness

The graph indicates that increasing teak powder up to 60% improves hardness. All compositions exceed the standard range (68–105 BHN), indicating excellent mechanical properties. The 60% teak (with 20% brass powder and 20% epoxy resin) yields the best result, while 50% composition shows the lowest.

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| **TABLE 3.** Average Bending Test Results for Teak Wood Powder. | | |
| **Composition** | **Avg. Bending Stress (MPa)** | **Avg. Modulus of Elasticity (MPa)** |
| Teak 50% | 10.47 | 238.84 |
| Teak 55% | 19.93 | 152.57 |
| Teak 60% | 26.06 | 185.34 |

## Discussion of Teak Wood Powder Bending Test

The bending test results for teak wood powder composites reveal meaningful insights into the effect of filler content on flexural performance. As illustrated in Fig. 3, the bending stress increases with the percentage of teak powder, reaching a peak value of 26.06 MPa at 60% composition. This suggests a positive correlation between teak content and flexural strength, likely due to improved load distribution and enhanced particle interaction at higher filler concentrations. Conversely, the 50% composition yielded a significantly lower bending stress of 10.47 MPa, which may be attributed to inadequate bonding between particles and the epoxy matrix at lower filler volumes.

In contrast, the elastic modulus results shown in Fig. 4 exhibit a different trend. The 50% teak composition achieved the highest modulus of elasticity at 238.84 MPa, indicating the stiffest response under load. Meanwhile, the modulus dropped significantly to 152.57 MPa at 55% and slightly increased to 185.34 MPa at 60%. These variations suggest that while bending strength benefits from higher teak content, structural stiffness may decline beyond an optimal filler concentration due to possible agglomeration or poor matrix-filler integration.

For comparative purposes, the bending test results of mahogany wood powder composites are summarized in Table 4. Interestingly, the 50% mahogany composition outperformed the others, recording the highest bending stress (26.46 MPa) and modulus of elasticity (218.32 MPa). This reinforces the observation that an optimal filler-to-matrix ratio is critical for maximizing both strength and stiffness.

**Figure 3.** Influence of Teak Composite Percentage on Bending Stress.

**Figure 4.** Influence of Teak Composite Percentage on Elastic Modulus.

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| **TABLE 4.** Average Bending Test Results for Mahogany Wood Powder. | | |
| **Composition** | **Avg. Bending Stress (MPa)** | **Avg. Modulus of Elasticity (MPa)** |
| Mahogany 50% | 26.46 | 218.32 |
| Mahogany 55% | 21.10 | 147.21 |
| Mahogany 60% | 20.84 | 163.48 |

## Discussion of Mahogany Wood Powder Bending Test

The bending performance of mahogany wood powder composites presents a trend consistent with that of the teak-based samples, where the optimal filler percentage plays a key role in determining mechanical properties. As shown in Fig. 5, the 50% mahogany composition yielded the highest bending stress, measured at 26.46 MPa. This result suggests that at this ratio, the interaction between the mahogany powder and epoxy binder reaches an effective balance, promoting strong interfacial adhesion and efficient stress transfer. However, increasing the filler content to 55% and 60% led to a decline in bending stress, likely due to reduced bonding efficiency and the tendency of excess filler to interfere with the matrix continuity.

**Figure 5.** Influence of Mahogany Composite Percentage on Bending Stress.

A similar pattern is observed in the elastic modulus values depicted in Fig 6. The 50% composition once again showed the best performance, recording the highest modulus of elasticity at 218.32 MPa, indicating superior structural stiffness. This reinforces the hypothesis that this ratio offers the most favorable distribution of stress under bending loads. In contrast, the 55% composition exhibited a sharp decline to 147.21 MPa, emphasizing the detrimental effect of excessive filler on the stiffness and uniformity of the composite. These findings underscore the importance of precise filler-to-matrix ratio selection in optimizing the mechanical characteristics of natural fiber-reinforced composites.

**Figure 6.** Influence of Mahogany Composite Percentage on Elastic Modulus.

## Relationship Between Friction Force, Hardness, and Bending in Teak and Mahogany Powders

This study explores the correlation between inclined-plane frictional force, Brinell hardness, and bending properties. Teak powder, with a maximum hardness of 125.12 kg/mm², exhibited greater resistance to friction-induced deformation, while mahogany reached 105.95 kg/mm² [19]. Conversely, mahogany showed slightly higher bending stress (26.46 MPa) than teak (26.06 MPa), indicating better performance under flexural loads. These findings suggest that although teak performs better in resisting wear, mahogany provides superior deformation tolerance under bending [20].

# CONCLUSION

Based on the experimental results and discussions, it can be concluded that the composition of teak and mahogany wood powder significantly influences the mechanical properties of the composite materials. The highest hardness was achieved using 60% teak wood powder (125.12 kg/mm²), while the optimal bending strength was obtained at 50% mahogany wood powder (26.46 MPa), indicating that the increase in teak content tends to enhance hardness, whereas the mahogany composition performs best at a moderate level. The most optimal formulation for brake pad applications combines 60% teak wood powder, 20% brass powder, and 20% epoxy resin for maximum hardness, and 50% mahogany wood powder for superior flexural strength. Therefore, both combinations offer promising potential as alternative eco-friendly brake pad materials. For future studies, it is recommended to conduct friction tests under realistic operational conditions to determine the coefficient of friction and braking effectiveness, especially under varying temperatures and humidity levels. Moreover, further optimization of processing parameters, such as sintering pressure and temperature, is necessary to improve wear resistance, frictional durability, and long-term performance stability of the composite material.

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