http://jurnal.unmer.ac.id/index.php/jtmt
TRANSMISI
ISSN (print): 9-772580-228020
ISSN (online): 2580-2283

Effect of Reinforcement Type Variation on Mechanical Properties of Epoxy Composite

Ahamd Norca Kurnia Zen 1[a*], Jumiadi 2[a] and Ike Widyastuti 3[a]

[a] *Department of Mechanical Engineering, Faculty of Engineering, University of Merdeka Malang, Jl. Terusan Raya Dieng 62-64, Malang, 65146, Indonesia*
**Corresponding author email: ahmadnorca@gmail.com*

ARTICLE INFORMATION

Received: 21 Februari 2025
Revised: 10 Maret 2025
Accepted: 10 Maret 2025
Published: 11 Maret 2025

ABSTRACT

This research aims to examine the mechanical characteristics of polymer matrix composites reinforced with filler from various types of wood powder. The types of wood used are mahogany, sengon, and Dutch teak. The composites were fabricated using the hand lay-up method with a composition of 90% resin and 10% wood powder. A specimen without the addition of wood powder was also prepared for comparison. In this research, the mechanical properties tested were bending strength and impact resistance (ASTM D5687 standards). The bending test was performed using the 3-point bending method with a Universal Test Machine, while the impact test was conducted using the Charpy Test method. The bending test results indicated that the composite reinforced with mahogany achieved the highest bending stress value of 136.02 N/mm², an increase of 20% compared to the composite without wood powder reinforcement. The impact test results showed no significant changes in impact resistance values, with an F-value of less than 5% in the ANOVA analysis.

Keywords: polymer composite, wood dust, mahogany, sengon, dutch teak.

DOI: 10.26905/jtmt.v21i1.14737

1. Introduction

Indonesia is an agrarian country rich in wood-producing plants. These plants are widely used for various purposes, from large-scale industry to small industries and household needs. According to data from Indonesia's statistical agency, the country has a forest area of 125.793,18 thousand hectares, of which 23.24% is designated as permanent production forest, and 21.3% is limited production forest [1].

Wood has unique material properties, making it widely used for construction purposes. The growing demand for wood and the potential decline in forest resources require efficient use of wood by industries. One way to maximize the potential of wood is by utilizing sawdust waste from production as a valuable product. Sawdust waste is commonly found at sawmills or furniture manufacturing companies. This waste is usually used as fuel or sometimes simply discarded[2].

In Indonesia, the total amount of sawn wood has reached 2.7 million m³ per year, with sawmill waste estimated at 1.4 million m³ per year[1]. This sawmill waste causes numerous issues, from decomposition when left to pile up to pollution problems when burned. These effects can have a negative impact on the surrounding environment. One solution is to repurpose sawmill waste into value-added products using applied technology.

The use of composite materials has become common in various industries. The adaptable properties of composites and the relatively simple manufacturing process make them a popular choice across multiple sectors. Composites have the advantage of being lighter than metals while offering mechanical properties comparable to those of metals. They are also environmentally friendly, as many of the raw materials are natural, and the waste produced from the manufacturing process is minimal[3].

Sawdust is a type of natural fiber with a density of 1.3-1.4 g/cm³[4]. With its light density, sawdust has the potential to be engineered into an environmentally friendly product. In composites, sawdust can serve as a filler or reinforcement. The use of wood fibers as a filler can enhance the strength and durability of the resulting composite[5]. Sawdust-based composites can be used to make lightweight engine components, especially for applications where weight loads are not critical. Components such as casings or engine covers can be made from sawdust composites that are compacted or mixed with resin. This helps reduce the overall weight of the engine, which is especially important in the automotive, transportation, or portable equipment industries.

Previous research has demonstrated various benefits of composites reinforced with wood powder. Composites reinforced with teak wood powder at a temperature of 180°C can achieve performance levels close to those of commercially available brake pads[6]. A composite with a mixture of 15% sawdust can be used as a wall panel, providing a flexural strength of 7.18 MPa and a compressive strength of 58.42 MPa[7]. A composite mixture of wood powder and coconut fiber can be utilized as a sound absorber, achieving a loss value of up to 50.95 dB[8].

Based on this detail, this research is conducted with the aim of identifying the characteristics of composite materials with various types of wood powder as reinforcement. The material characteristics investigated include bending strength and impact resistance. Materials with higher bending strength are better able to withstand applied loads without permanent damage or deformation. This is especially important in applications that require high structural strength, such as skyscrapers or offshore platforms. Materials with high impact capabilities are important for applications where sudden loads may occur, such as in accidents or rapid mechanical failure. These materials are better able to absorb energy and prevent fatal damage or structural failure.

2. Methodology of Research

2.1 Material

The wood powder used was from Dutch teak, sengon, and mahogany trees. The wood powder was first filtered separately using a 60-mesh sieve. Each sieved result was then filtered again using an 80-mesh sieve. This process ensures that particles smaller than 60 mesh are filtered out, so only particles of 60 mesh size are used.

Figure 1 Wood powder

Epoxy resin was used as the matrix for the composite. The mixing ratio between the base resin and hardener was 2:1, meaning 66.6% base resin was mixed with 33.3% hardener.

Figure 2 Epoxy resin

2.2 Specimen Dimension

The bending test specimen was prepared according to ASTM D5687 standards with dimensions of 128 mm in length, 13 mm in width, and 4 mm in thickness.

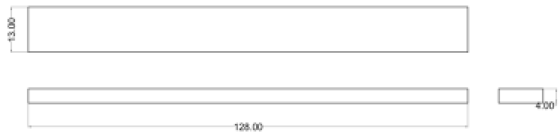

Figure 3 Bending test specimen ASTM D5687

The impact test specimen was prepared according to ASTM D6110 standards with dimensions of 126 mm in length, 12.6 mm in width, 12.6 mm in thickness, and a notch depth of 2 mm.

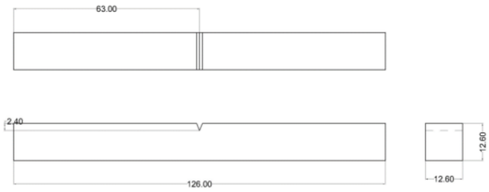

Figure 4 Impact test specimen ASTM D6110

2.3 Manufacture of Composite Specimen

The specimen preparation was carried out with the following steps:

1. Filter Dutch teak, mahogany, and sengon wood powder to a 60-mesh size.
2. Mix resin with hardener in a ratio of 66.6% resin to 33.3% hardener.
3. Combine the resin mixture with wood powder in a ratio of 91% resin mixture to 9% wood powder.
4. Stir the mixture clockwise by hand for 5 minutes.
5. Pour the mixture into a mold.
6. Allow 2-3 days for the specimen to dry.
7. Remove the specimen from the mold.
8. Sand the specimen to achieve dimensions in accordance with ASTM D5687 standards for bending test specimens and ASTM D6110 for impact test specimens.

9. Repeat the same procedure for a pure resin specimen without wood powder as a comparison.
10. Prepare three specimens for each wood type and the pure resin mixture without wood powder.

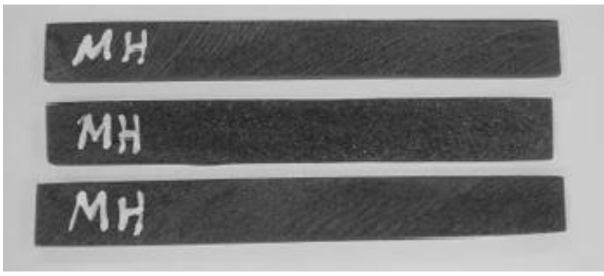

Figure 5 Bending test specimen

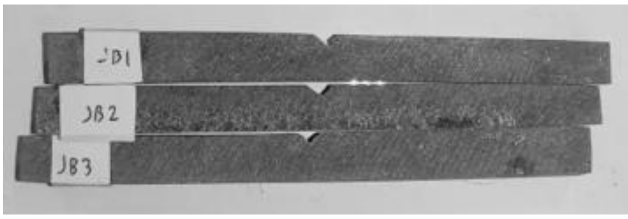

Figure 6 Impact test specimen

2.4 Bending Test

The bending test was conducted using the three-point bending method. This method involves using two points as supports and one point on top as the load applicator. The test was performed using a universal test machine. The result provides the force required to apply pressure to the specimen. The bending stress value is obtained using the following formula:

$$\sigma_B = \frac{M_{max} \times y}{I}$$

Figure 7 Bending test

2.5 Impact Test

The impact test was conducted using the Charpy method. The data collection process for the impact test begins by operating the impact testing machine without a specimen to determine the initial swing angle (α_0) at point A. After the pendulum swings, the final swing angle (β_0) is recorded at point B. In the next test, the process is repeated with a specimen in place. This provides the initial swing angle (α_1) at point A, and after the pendulum swings, the final angle (β_1) at point B is recorded. The specimen is positioned horizontally, supported at both ends. The pendulum then swings freely and strikes the specimen directly at the back of the notch. Impact strength value is obtained using the following formula:

$$HI = \frac{E_{ak}}{h \times l}$$

Figure 8 Impact test

2.6 Dependent Variable

The dependent variables in this research include:

1. Result from the bending test, covering tensile strength, torsional moment, and moment of inertia.
2. Result from the impact test, covering the energi required to break the specimen.

2.7 Independent Variable

The independent variable used in this research is the types of wood powder used as a composite filler.

2.8 Location

This research was conducted at physichal metallurgy laboratory, faculty of engineering, merdeka university malang.

2.9 Duration

This research was conducted over period of five months, from October 2023 until February 2024.

3. Result and Discussion

3.1 Bending Test

In this research, a bending test was conducted on three variations of test specimens, with three repetitions for each type of specimen. The bending test was performed to determine the deflection and bending stress values for each composite variation.

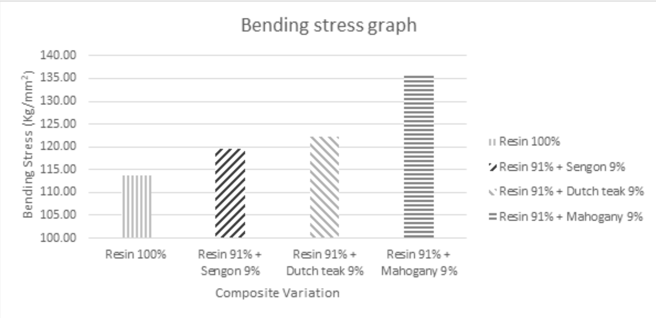

Figure 9 Bending stress graph

Figure 9 show that the composite with a resin + mahogany mixture produced the highest average bending stress at 136.02 kg/mm². This is followed by the resin + Dutch teak composite, with an average bending stress of 121.76 kg/mm². The resin + sengon composite yielded the lowest average bending stress at 119.61 kg/mm². Nevertheless, these composites still have a higher average bending stress than the pure resin composite, which has an average bending stress of 113.13 kg/mm².

With the ability to withstand higher bending stress, resin + mahogany composites will be more resistant to severe working conditions and are not easily damaged or worn. This is very important in machine components that often operate under dynamic conditions and are exposed to repeated loads or forces that can cause deformation. Stronger and more durable components can reduce the need for maintenance and component replacement, leading to long-term cost savings.

Table 1 Modulus of Elasticity and Modulus of rupture Value

Wood type	MoE (Mpa)	MoR (Mpa)
Sengon [9]	7002.6	20.65
Dutch teak [10]	7597	63
Mahogany [11]	7923.7	74.7

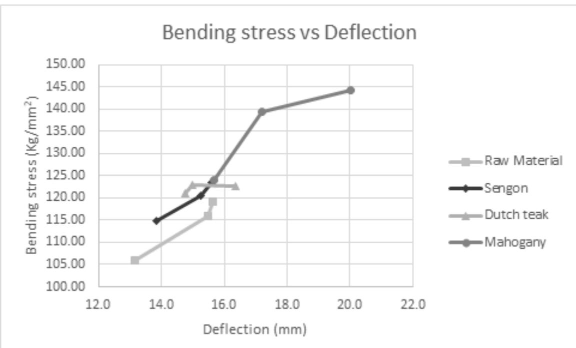

Figure 10 Bending stress vs deflection

The resin and mahogany composite produced the highest bending stress value because mahogany wood possesses superior mechanical properties, such as a higher modulus of elasticity and modulus of rupture, compared to Dutch teak and sengon wood. Mahogany wood powder also interacts more effectively with epoxy resin, resulting in the best composite strength among the tested specimens. Adding mahogany wood powder can increase the bending stress of the resin by up to 20% compared to the resin without added powder.

In figure 10, a direct relationship between bending stress and deflection can be observed. As deflection increases, bending stress also increases. This occurs because producing a large deflection requires a substantial load. A higher load, in turn, results in greater bending stress.

3.2 Impact Test

In this research, an impact test was conducted on three specimen variations, with three repetitions for each type of specimen. The impact test was performed to determine the energy required to break the test specimen, the impact strength, and the type of fracture for each composite variation.

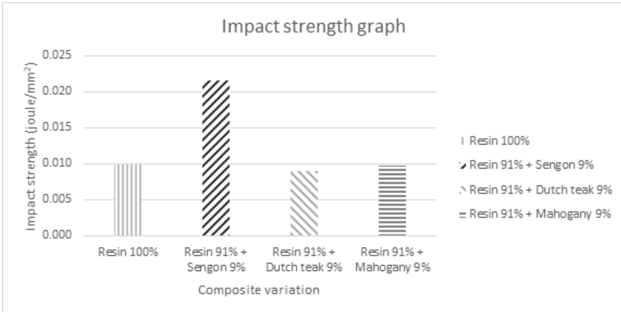

Figure 11 Impact strength graph

In figure 11, most specimens show an impact strength value around 0.01 joules/mm². However, the third specimen from the resin and sengon mixture exhibits a significantly higher impact strength of 0.044 joules/mm², much greater than the other specimens. This occurs because, in the composite mixing process with randomly oriented reinforcement, the sengon particles within the resin gathered around the fracture area, thereby increasing the impact strength value of that specimen. The addition of epoxy resin or polymer to sengon wood to form a composite material can increase impact strength. This resin fills the space between the wood fibers and increases the adhesion strength between the wood components, as well as increasing resistance to damage due to impact.

The average values indicate that there is no significant difference in impact strength across the different mixture variations, except for the sengon mixture due to one test specimen with a high impact strength value. This is further supported by the ANOVA analysis.

Table 2 Impact strength ANOVA table

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.000364	3	0.000121	1.269592	0.348461	4.066181
Within Groups	0.000765	8	9.57E-05			
Total	0.00113	11				

Table 2 above presents the ANOVA results, where SS (sum of squares) indicates the total squared value, df (degree of freedom) shows the degrees of freedom, MS (mean square) represents the average square, F displays the calculated F-value, P-value indicates the level of significance, and F crit shows the critical F-value. It can be seen that F = 1.269592 is below F crit = 4.066181. This result indicates that the initial hypothesis—that the type of wood powder used as reinforcement significantly affects the impact strength of the specimen—is rejected.

The type of wood powder does not significantly affect impact strength due to the low proportion of wood powder reinforcement mixed with the resin, which is only 9% of the total composite. Additionally, the randomly oriented mixing causes the wood powder to be distributed randomly rather than concentrated at the impact point, which prevents it from maximizing resistance to impact loads.

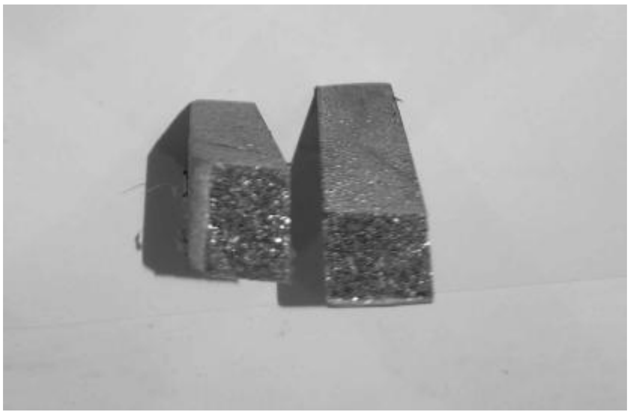

Figure 12 Fracture of specimen

From Figure 12, the type of fracture from the impact test specimen can be observed. The fracture surface appears smooth and flat, without any signs of plasticity. The fracture edges also appear sharp, with no signs of elongation or strain before the fracture occurred. This indicates that the specimen has brittle fracture characteristics, where the material breaks immediately upon sudden impact pressure without significant deformation. The ratio of resin to reinforcing material (such as fiber, wood particles, or sawdust) greatly affects the fracture properties. If the composite contains too much resin and too little reinforcing material, the material will become more brittle because the resin will dominate and the elastic properties of the reinforcing material that can absorb the load will be limited. Conversely, if the reinforcing material is too much, the resin may not be enough to bond the reinforcing material tightly, reducing the overall performance of the material.

4. Conclusion

From the experimental research on composites with reinforcement variations of mahogany, dutch teak, and sengon wood powder, the following conclusions can be drawn:

1. The highest bending stress was obtained in the composite with mahogany powder, with an average bending stress of 136.02 kg/mm², showing an increase of 20% compared to the composite without wood powder reinforcement.
2. Bending stress and deflection have a directly proportional relationship; as deflection increases, bending stress also increases.
3. The highest impact strength was obtained in the composite with sengon wood powder, with an average impact strength of 0.022 joules/mm². However, in the impact test, no significant influence was found from the type of wood powder mixture due to the widely dispersed distribution of the powder within the composite.

References

[1] B.-S. Indonesia, ‘Statistics of Forestry Production 2023’. Accessed: Oct. 05, 2024. [Online]. Available: https://www.bps.go.id/en/publication/2024/07/26/3a38028576970e086c1cf32f/statistics-of-forestry-production-2023.html

[2] N. L. P. Y. Anggreni, I. P. E. Indrawan, and P. K. Suparyana, ‘Wirausaha Masyarakat Desa Mendoyo Kabupaten Negara Dalam Pemanfaatan Limbah Kayu Sebagai Produk Kerajinan Tangan Yang Ramah Lingkungan’, *Jurnal Pengabdian Kepada Masyarakat Widya Mahadi*, vol. 2, no. 2, Art. no. 2, Jun. 2022, doi: 10.59672/widyamahadi.v2i2.1951.

[3] S. Arif, D. Irawan, and M. Jainudin, ‘Analisis sifat mekanis perbandingan campuran komposit serbuk gergaji kayu jati dengan matrik epoxy untuk material kampas rem cakram’, *Jurnal Technopreneur (JTech)*, vol. 7, no. 2, pp. 58–63, 2019.

[4] S. T. Dwiyati, A. Kholil, and F. Widyarma, ‘Pengaruh penambahan karbon pada karakteristik kampas rem komposit serbuk kayu’, *Jurnal Konversi Energi dan Manufaktur*, pp. 108–114, 2017.

[5] Ö. Andiç-Çakir, M. Sarikanat, H. B. Tüfekçi, C. Demirci, and Ü. H. Erdoğan, ‘Physical and mechanical properties of randomly oriented coir fiber–cementitious composites’, *Composites Part B: Engineering*, vol. 61, pp. 49–54, May 2014, doi: 10.1016/j.compositesb.2014.01.029.

[6] F. Yudhanto and S. W. Yakti, ‘Karakterisasi Bahan Kampas Rem Sepeda Motor Dari Komposit Serbuk Kayu Jati’, *Quantum Teknika: Jurnal Teknik Mesin Terapan*, vol. 1, no. 1, pp. 19–27, 2019.

[7] S. Zuraida and S. Pratiwi, ‘Analisis Fisik dan Mekanik pada Pengembangan Panel Komposit Limbah Serbuk Kayu’, *JOURNAL OF APPLIED SCIENCE (JAPPS)*, vol. 2, no. 1, pp. 061–066, Mar. 2020, doi: 10.36870/japps.v2i1.162.

[8] M. I. Alamsyah, A. M. Maghfiroh, and F. Ashari, ‘Pembuatan Komposit Berbahan Dasar Sabut Kelapa dan Serbuk Kayu sebagai Peredam Suara’, *Jurnal Teknik Industri*, vol. 26, no. 02, pp. 36–48, 2023.

[9] T. M. Wicaksono, A. Awaludin, and S. Siswosukarto, ‘Analisis Perkuatan Lentur Balok Kayu Sengon Dengan Sistem Komposit Balok Sandwich (Lamina Dan Plate)’, *INERSIA lnformasi dan Ekspose Hasil Riset Teknik Sipil dan Arsitektur*, vol. 13, no. 2, pp. 129–140, 2017.

[10] W. Darmawan, D. Nandika, B. D. Hasna Afaf, I. Rahayu, and D. Lumongga, ‘Radial Variation in Selected Wood Properties of Indonesian Merkusii Pine’, *Journal of the Korean Wood Science and Technology*, vol. 46, no. 4, pp. 323–337, Jul. 2018, doi: 10.5658/WOOD.2018.46.4.323.

[11] 'Sifat Fisik dan Mekanik Komposit Papan Partikel Berdasarkan Variasi Ukuran Serbuk Kayu Mahoni (Swietenia Macrophylla) Sebagai Material Alternatif : Papan Komposit | Jurnal TAMBORA', Oct. 2023, Accessed: Dec. 01, 2023. [Online]. Available: https://jurnal.uts.ac.id/index.php/Tambora/article/view/2714