Tensile Properties of Wood Sawdust Fibre Reinforced Epoxy Composites

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Abstract: This study conducts an extensive examination of the tensile properties of epoxy resin composites strengthened with wood sawdust fiber. It emphasizes the potential of these composites as a sustainable and cost-effective substitute in the automotive industry. Sawdust particles with a mesh size of 100 and weights of 10%, 20%, and 30% are mixed with epoxy resin in this experiment so that tensile stress and tensile modulus under load can be observed in detail. The fabrication process involved the manual lay-up of tensile specimens. The results indicate that the tensile properties of composites containing 20% sawdust are an unexpected 30% superior to those comprising 10% filler loading. In contrast, micrograph tensile fracture examinations unveiled the presence of agglomeration and air bubble, factors that compromised the accuracy of the findings. The results demonstrate the critical nature of optimizing the sawdust content to attain the optimal equilibrium in the mechanical properties of composites. It is recommended that future applications implement additional microstructural control measures and refine the fabrication process to enhance precision and dependability.

Keywords: fiber; sawdust; epoxy; composite; filler.

1. Introduction

Traditionally, sawdust has been regarded as a byproduct of various timber activities, such as sawing, cutting, sanding, drilling, chipping, and turning of hardwood in the timber industry. Sawdust is the aggregate term for these tiny chips or particles that come from these procedures (Medina-Martinez et al., 2023; Teischinger, 2023). Because sawdust is flammable and can pollute the air, it has traditionally been burned or disposed of in landfills, raising environmental issues. Aware of the need for long-term fixes, scientists have looked at different uses for sawdust, turning waste into a useful material. These days, sawdust is used for a wide range of purposes, including as an oil spill absorbent, an organic fertilizer, an additive to cement, and, most famously, as a reinforcement in brake pad application (Anggraeni et al., 2022; Elakhame et al., 2017; Wei et al., 2023).

(Ali et al., 2022) explore the effects of different concentrations of sawdust fibre on the mechanical characteristics of epoxy composites that are reinforced with sawdust fibre. There are three different weight compositions of sawdust: 75, 80, and 85%. In comparison to other concentrations, the results of the investigation indicate that sawdust filler, which accounts for 80% percent of the total, possesses the highest mechanical properties. This is because reinforcements have a synergistic effect on the structure of the system.

The same kind of experiment was carried out by (Koyuncu, 2022) on the influence of sawdust concentration on the mechanical characteristics of pine sawdust concentration-reinforced epoxy composites at the same time. When compared to different weight percentages of pine sawdust composites, the results showed that 15% weight fractions of pine sawdust exhibited mechanical properties. The maximum tensile strength of the composite was 7. MPa, and the flexural strength was 8.9 MPa. It was determined that the development of a favorable interfacial bond between the 15 wt.% sawdust and epoxy resin played a significant role in the improvement in mechanical parameters.

This study aims to examine the effects of varying sawdust concentration on the tensile properties of epoxy composites reinforced with wood sawdust. An analysis and comparison will be conducted on epoxy composites containing three distinct concentrations of sawdust filler: 10 wt.%, 20 wt.%, and 30 wt.%.

2. Methodology

The primary material used in this study is sawdust obtained from sawmills and the wood industry in Malaysia. The sawdust, which has a particle size of 100 mesh, functions as the filler, while the selected polymer composite is epoxy resin (Epikote 828), serving as the binder. The test specimens are formed by applying the epoxy hardener as a curing agent to solidify the epoxy resin.

Before mixing, drying the wood sawdust in a vacuum oven for 24h at a temperature of 80 °C achieves the optimal moisture level. After dehydration, mixing the dehydrated sawdust with epoxy resin and hardener, specifying the precise ratios in Table 1 and Table 2. This will ensure that there is a consistent proportion of epoxy resin to hardener that is 3:1 (Cionita et al., 2022). The sawdust weightings of the three samples will be 10%, 20%, and 30%, respectively, resulting in a total of 200 grammes for each sample. Next, vigorously combine the components in a container until a consistent mixture is obtained. After that, the mixture that was produced will be poured into the molds that are used for the flexural and tensile bars, and it will be left there to go through the curing process. To recreate the complete procedure for the remaining two samples, each with different material compositions, we will repeat the procedure.

Table 1. Material compositions in weight percent (%).

Materials	Weightage (wt.%)		
	Sample A	Sample B	Sample C
Sawdust	10	20	30
Epoxy Resin	67.5	60	52.5
Epoxy Hardener	22.5	20	17.5

Table 2. Material compositions in weight (g).

Materials	Weightage (g)		
	Sample A	Sample B	Sample C
Sawdust	20.0	40.0	60.0
Epoxy Resin	135.0	120.0	105.0
Epoxy Hardener	45.0	40.0	35.0
Total	200.0	200.0	200.0

After the mixing process, the mixture will be placed in the molds and left to cure at room temperature for a period of 24 hours. After complete curing, the specimens will be removed from the molds and transferred into appropriately labelled plastic bags. The bags will be accurately labelled as Sample A (10% sawdust), Sample B (20% sawdust), and Sample C (30% sawdust). For analysis purposes, a total of 7 tensile specimens will be taken in each sample according to ASTM D638-14 (ASTM D638-14).

The Instron 3369, a type of universal testing machine, is used to determine the tensile properties of the composite specimens. The machine operates at a cross-head speed of 2 mm/min. In addition, Soptop optical microscopy is used to analyze the tensile fractures in the composite specimens.

3. Result and Discussion

Figure 1 illustrates the tensile stress-strain curve of wood sawdust reinforced epoxy composites. The graph indicates that the composite with 20 wt.% wood sawdust filler in epoxy resin attains the highest tensile strength compared to other concentrations. With an increase in filler loading from 10 to 20 wt.% of sawdust, the tensile strength of the composites experiences a notable enhancement, rising by approximately 30% from 19 MPa to 27 MPa, as detailed in Table 3. The decrease in tensile strength observed with the maximum loading of 30% sawdust filler in epoxy, reaching 18 MPa, can be attributed to the potential challenges associated with overloading the composite.

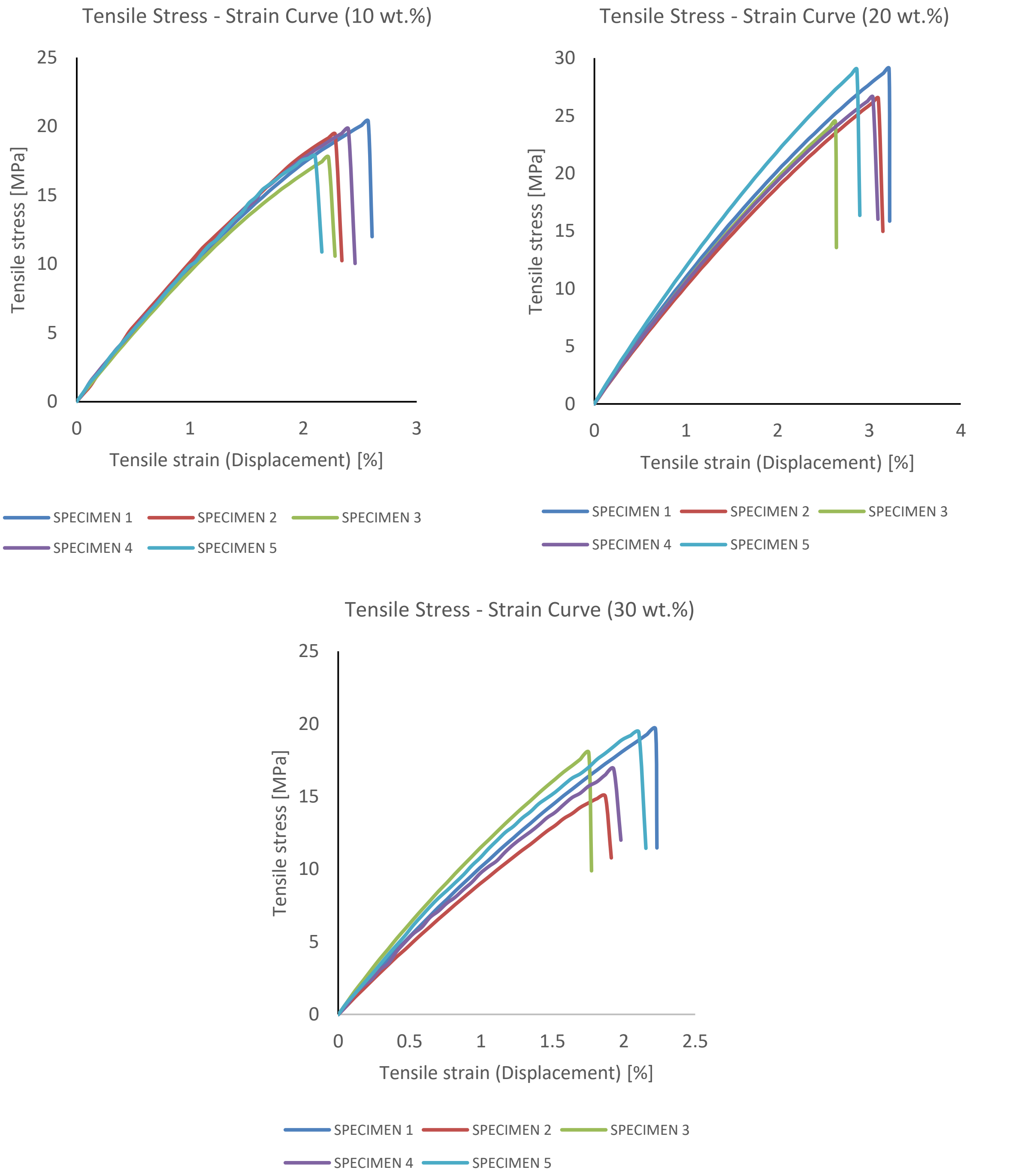

Figure 1. Tensile stress – strain curve of wood sawdust reinforced epoxy composites.

Table 3. Comparison of average tensile test results.

Sawdust Content	Modulus (Automatic Young's) [MPa]	Tensile stress at Tensile strength [MPa]	Displacement at Tensile strength [mm]
Sample A (10% sawdust)	1131	19	1.322
Sample B (20% sawdust)	1134	27	1.692
Sample C (30% sawdust)	1165	18	1.128

In this case, the optimal concentration appears to be 20 wt.% sawdust, striking a balance between reinforcing the composite and maintaining effective interfacial bonding with the epoxy resin, as depicted in Figure 2b. The micrograph of the tensile fracture for the 20% sawdust filler reveals a well-dispersed and homogeneous distribution in the epoxy composites. This even dispersion is crucial for reinforcing the composite material effectively (Olonisakin et al., 2022). At lower concentrations, the reinforcing action may not be maximized, leading to a decrease in tensile strength (Figure 2a). Conversely, higher concentrations could result in issues such as uneven spreading, aggregation, or insufficient epoxy resin to adequately connect the sawdust particles, thereby diminishing the tensile strength (Figure 2c) (Valvez et al., 2021). Addressing the filler-matrix interaction and ensuring consistent sawdust dispersion throughout the epoxy resin are critical considerations (Sienkiewicz et al., 2022). The 30% concentration may face diminishing returns due to the potential challenges of maintaining homogeneity. Consequently, the 20 wt.% concentration emerges as a suitable compromise, yielding improved tensile strength for the wood sawdust-reinforced epoxy composite.

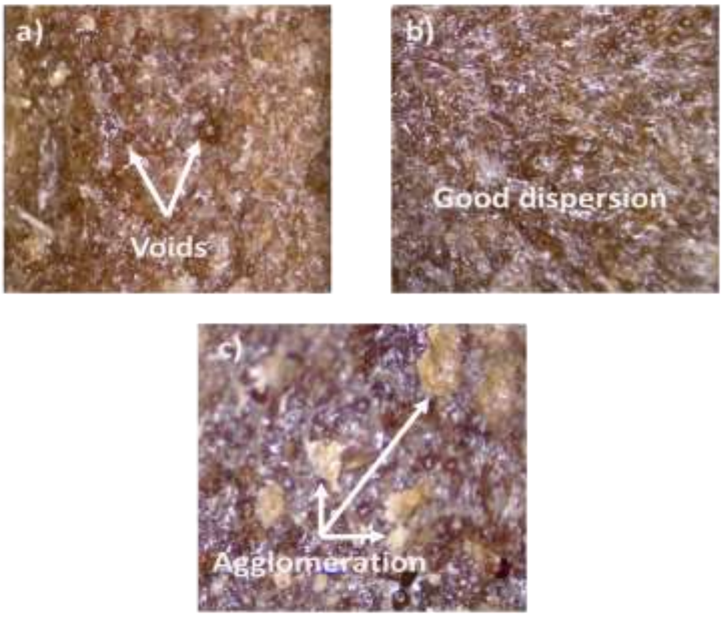

Figure 2. Tensile fracture micrographs of sawdust at; a) 10%, b) 20% and c) 30% of sawdust.

According to the findings presented in Table 3, the tensile modulus of sawdust-reinforced epoxy composites exhibits a pattern that was rather unexpected. In contrast to the linear development that was anticipated with increasing sawdust concentrations, the data exhibit variations. When it comes to the tensile modulus, Sample B (20% sawdust) is particularly interesting because it has the highest value, which is 1165 MPa. This number is higher than the values of Sample A (10% sawdust), which is 1131 MPa, and Sample C (30% sawdust), which is 1134 MPa. According to the findings of earlier researchers, the drop in tensile properties that corresponds to an increase in filler content can be attributed to several different variables. One of the factors that will have an impact on the interfacial bonding between the filler reinforcement and the polymer matrix is the dispersion of the filler in the polymer. Poor dispersion of filler in epoxy caused agglomeration and uneven distribution, as depicted in Figure 2c. The second factor that has contributed to decreasing tensile properties is the poor wettability of the filler by matrix, which is due to the higher amount of filler material.

According to the data in Table 3, the tensile strain of wood sawdust reinforced epoxy composites experienced an increase from 1.322 mm to 1.692 mm as the filler loading raised from 10 wt.% to 20 wt.%. By increasing the filler content from 20 wt.% to 30 wt.%, there has been a reduction in the tensile strain of roughly 67%. Sample B, containing 20% sawdust, exhibited the highest tensile strain, indicating that the composite is more flexible and ductile. Through analyzing the micrograph of the tensile fracture of Sample B in Figure 2b, it is evident that the filler is uniformly dispersed and well-mixed with the epoxy resin. This results in a stronger and more flexible material, allowing for more deformation before failure (Dhal et al., 2023). The dropped strain that was noted can be attributed to the difficulties associated with elevated filler concentrations, such as agglomeration and irregular dispersion. These issues hinder the material's ability to endure consistent deformation under stress conditions (Jagadeesh et al., 2021; Rueda et al., 2017). The findings of this research point out the significance of conducting careful optimization of the sawdust content in epoxy composites reinforced with wood sawdust in order to achieve the desired mechanical properties.

4. Conclusions

The influence of sawdust concentration on the tensile properties of wood sawdust-reinforced composites has been extensively examined. The study's findings indicate that the inclusion of 20 wt.% of sawdust in the composites contributed to an increase in their tensile strength, tensile modulus, and tensile strain. The increased concentration of sawdust in epoxy composites leads to the agglomeration and aggregation of the filler in the composite, which negatively impacts the tensile strength, tensile modulus, and tensile strain results. The tensile properties of the composites depend on the concentration of filler content and the interfacial adhesion between the filler and the matrix epoxy composites.

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