ADMI JUIT Jurnal Ilmiah Teknik

JUIT Vol 4 No. 3 | September 2025 | ISSN: 2828-6936 (Print), ISSN: 2828-6901 (online), Page. 09-19

Analysis of Tensile Strength of Carbon Fiber and E-Glass Sandwich Composite Materials with Balsa Wood Core Based on Polyester

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Article History
Received : September 8, 2025
Revised : September 15, 2025
Accepted : September 16, 2025
Published : September 16, 2025

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Cite This Article:
Banowati, L., Bekti Suroso, & Robert Parulian. (2025). Analysis of Tensile Strength of Carbon Fiber and E-Glass Sandwich Composite Materials with Balsa Wood Core Based on Polyester. Jurnal Ilmiah Teknik, 4(3), 09–19.

DOI:
https://doi.org/10.56127/juit.v4i3.2291

Abstract: Sandwich composite is a type of structural composite material composed of two outer layers (skins) and a core material in the middle. There are various definitions of sandwich composites, but a key factor is the lightweight core, which reduces the material's specific weight, coupled with the rigidity of the skin layers that provide strength to the sandwich composite. This research aims to determine the tensile strength of carbon fiber and glass fiber sandwich composite materials with fiber orientations at 0°, ±45°, and (0,90)°, using a 3 mm thick core. The matrix used is polyester Yukalac 2250 BW-EX. Tensile testing is conducted following ASTM D3039 standards. Based on the tensile test results, the highest tensile strength is observed in the carbon-balsa/polyester sandwich composite with a 0° fiber orientation, achieving an average tensile strength of 152.71 MPa. On the other hand, the lowest tensile strength is found in the e-glass-balsa/polyester sandwich composite with a ±45° fiber orientation, with an average tensile strength of 12.34 MPa.

Keywords: carbon-E-glass sandwich composites, tensile strength, balsa wood core.

INTRODUCTION

Materials technology is developing rapidly. Humans always try to create new discoveries that are better than previous discoveries. Composite materials are one of the inventions that are widely used in the manufacture of unmanned aerial vehicle (UAV) structures because they have superior properties, are light, strong, stiff and resistant to corrosion and fatigue loads. The increasing demands of society for materials that are light but remain strong make it necessary to study and develop composite materials (Widodo, 2022).

A composite is a new material formed from a combination of two or more macroscopically different materials, where the combination of the two types of materials has different properties (Jones, 2025). Composites have several advantages, including being lightweight, strong, and corrosion-resistant. Composites are highly sought after because they meet the needs of modern society: strength yet lightness (Mallick, 2007).

Among the various types of wood, balsa wood has the best characteristics for use as a core. Previously, research has been conducted on the properties of balsa wood regarding the toughness properties of balsa wood (Mohammedi, 2013), flexural properties of sandwich composites with carbon fiber reinforcement and a wood core (Zaharia, 2017), composite sandwich panel with glass fiber and foam reinforcement (Li, 2014). The most widely used fiber-reinforced polymer composites are laminar structures, which are made by stacking and bonding thin layers of fiber and polymer to the desired thickness. The most widely used fiber-reinforced polymer composite is the laminate structure.made by stacking and bonding thin layers of fiber and polymer to the desired thickness. By changing the orientation of the fibers between layers in a laminate structure, a certain degree of anisotropy in the composite properties can be achieved (Ngo, 2020). By changing the orientation of the fibers between layers in a laminate structure, a certain degree of anisotropy in the composite properties can be achieved (Ngo, 2020).

Sandwich composites with balsa wood cores in sandwich structure construction have the advantages of environmental sustainability, low raw material costs, excellent specific mechanical properties, and thermal insulation properties (Galos, 2022). Furthermore, the research stated that shear stiffness and strength of balsa wood will increase along with increasing density (Antwi, 2014). Bending tests on hybrid sandwich composites using balsa wood cores with hemp and e-glass fiber reinforcement have been carried out (Banowati, 2022). Meanwhile, research on the tensile strength of sandwich composites with styrofoam and balsa wood cores using carbon/epoxy and e-glass/epoxy fibers with a fiber direction of (0.90)°. Based on the results of the tensile test comparison, the highest strength is in the carbon fiber/epoxy composite with a value of 479.20 MPa and the lowest value is in the e-glass fiber/epoxy with a value of 155.58 MPa (Banowati, 2022).Based on the background above, the author took this research and it is hoped that it can be used as a spar construction on an unmanned aerial vehicle (UAV), especially on the AerO-73K UAV because the structure of the UAV previously used e-glass fiber sandwich composite material with a foam core, which was overweight.

RESEARCH METHODS

The stages of this research were carried out systematically, starting with the literature study and continuing through to completion. A more detailed description of the research stages can be seen in Figure 1.

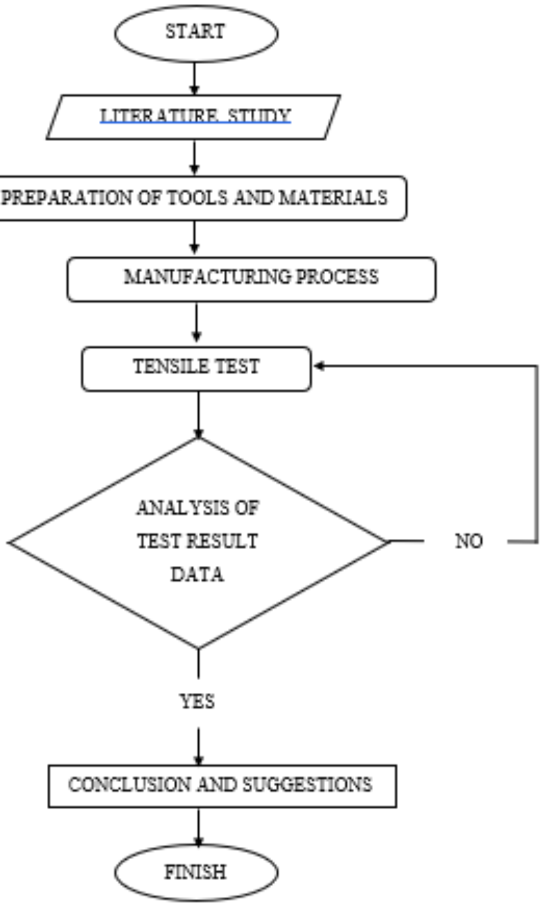


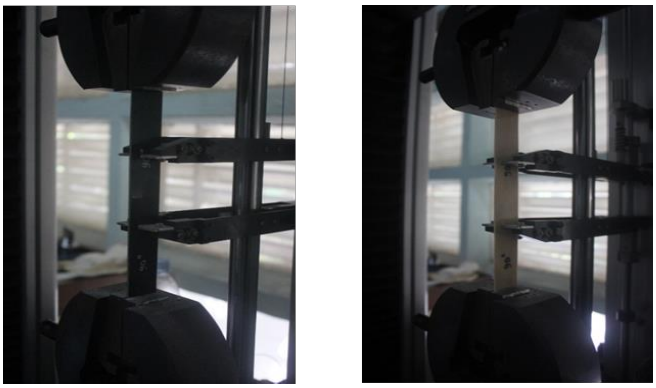
Figure 1. Research Flowchart

In this study, specimens were made using a combination of hand lay-up and vacuum bagging processes. Hand lay-up is the manual lamination of composites, followed by a vacuum bagging process that involves pressing the laminate of resin, fibers, and other layers using an airtight bag. Figure 2 shows the composite test specimen.

(a) (b)

Figure 2. Sandwich Composite Test Specimens: (a). Carbon-Balsa/Polyester (FC), (b). E-Glass-Balsa/Polyester (FG)

In this study, the fabrication of composite specimens followed the ASTM D 3039 standard for carbon-balsa/polyester sandwich composites and E-glass-balsa/polyester sandwich composites with fiber directions 0˚, ±45˚, and (0.90)˚, respectively. Tensile testing is carried out using a universal tensile testing machine, and the results are represented in a load vs elongation graph to obtain the maximum point load value. Figure 3 shows a visualization of the tensile testing process on sandwich carbon-balsa/polyester and sandwich e-glass-balsa/polyester sandwich composites.



(a) (b)

Figure 3. Sandwich Composite Tensile Test: (a) Carbon-Balsa/Polyester Fiber, (b) E-Glass-Balsa/Polyester Fiber

RESULT AND DISCUSSION

Figures 4, 5, and 6 show the graphs of the tensile test results of the carbon-balsa/polyester sandwich composites.

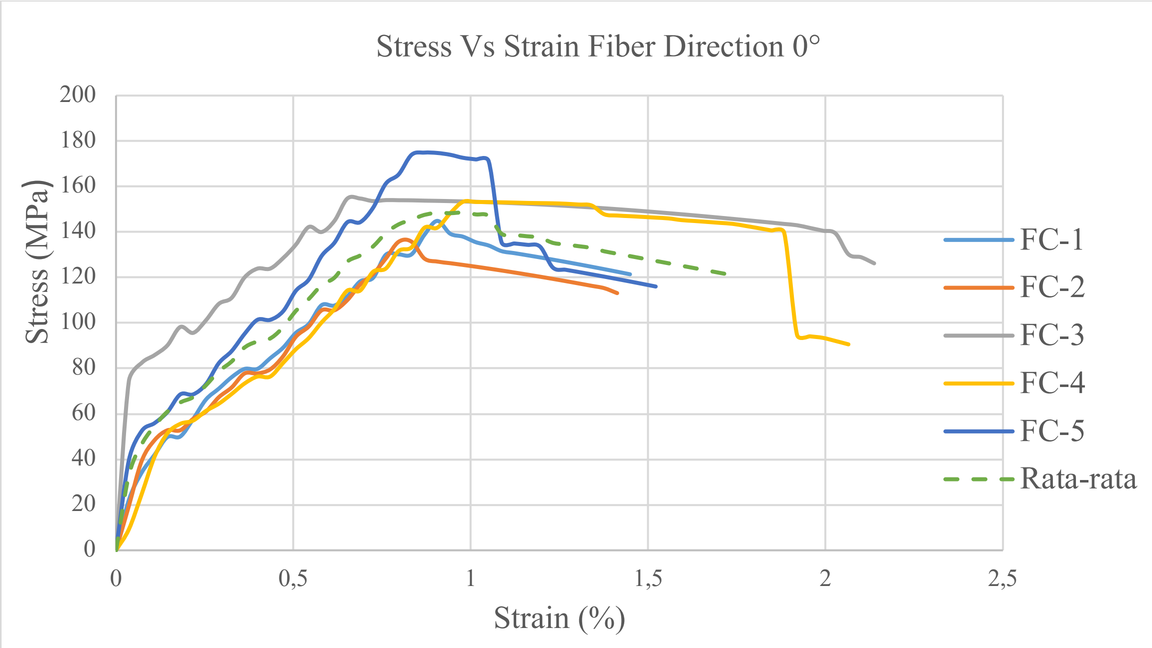


Figure 4. Stress and Strain Graph of Carbon-Balsa/Polyester Sandwich Composites with Fiber Direction Orientation 0˚

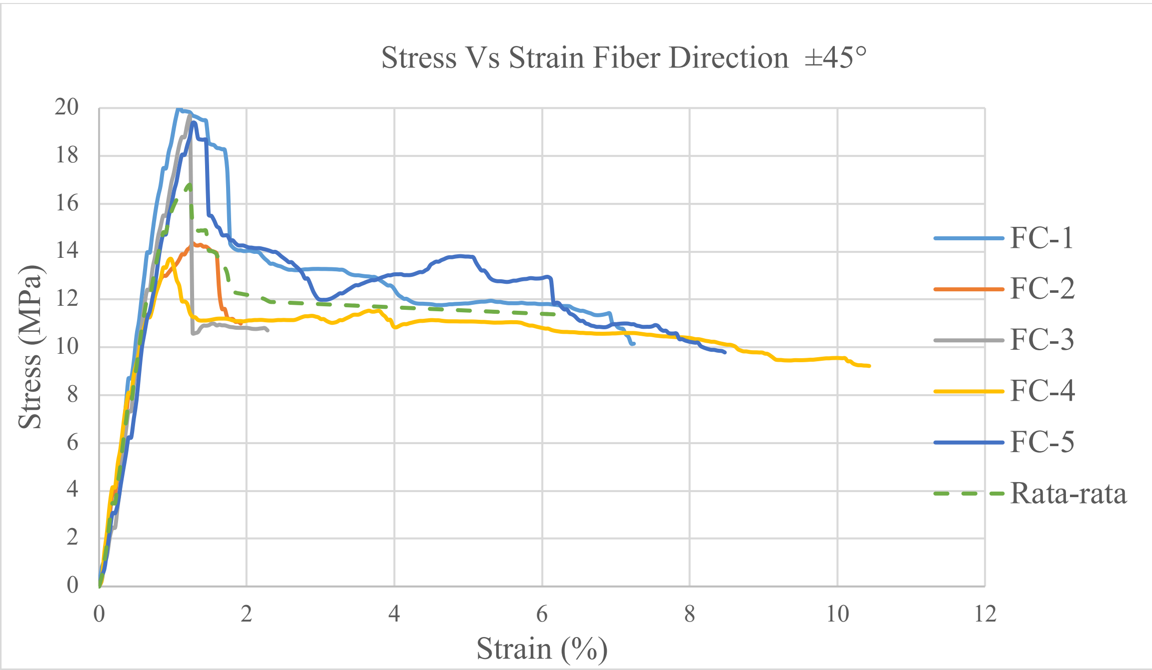


Figure 5. Stress and Strain Graph of Carbon-Balsa/Polyester Sandwich Composites with Fiber Direction Orientation ±45˚

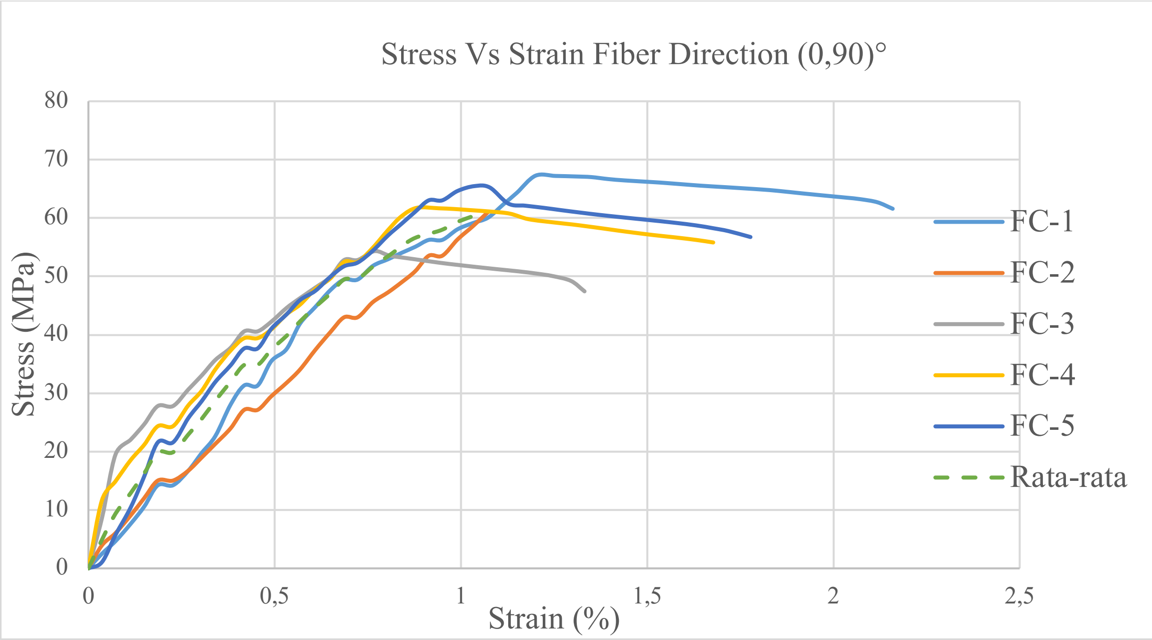


Figure 6. Stress and Strain Graph of Carbon-Balsa/Polyester Sandwich Composites with Fiber Direction Orientation (0.90)˚

Figures 7, 8, and 9 show the graphs of the tensile test results of the E-glass-palsa/Polyester sandwich composite, respectively.

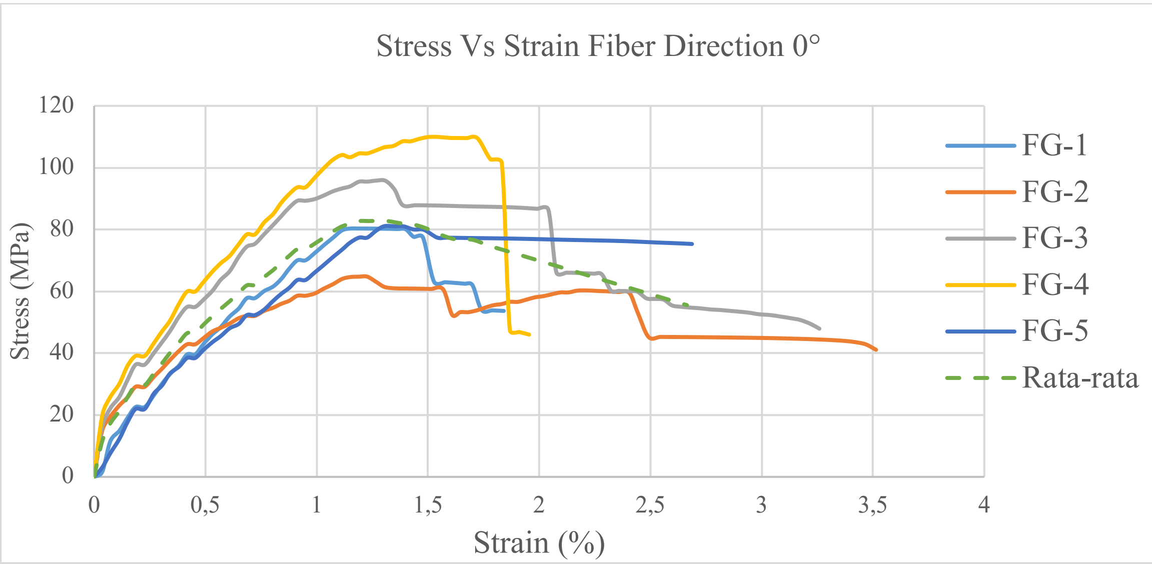


Figure 7. Stress and Strain Graph of E-Glass-Balsa/Polyester Sandwich Composites with Fiber Direction Orientation 0˚

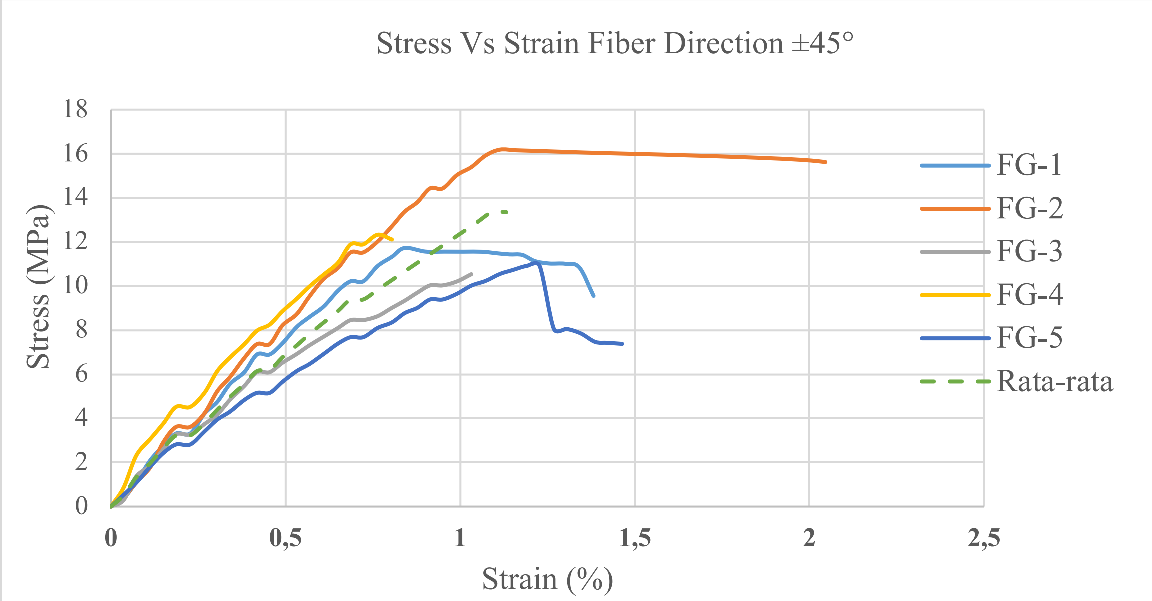


Figure 8. Stress and Strain Graph of E-Glass-Balsa/Polyester Sandwich Composites with Fiber Direction Orientation ±45˚

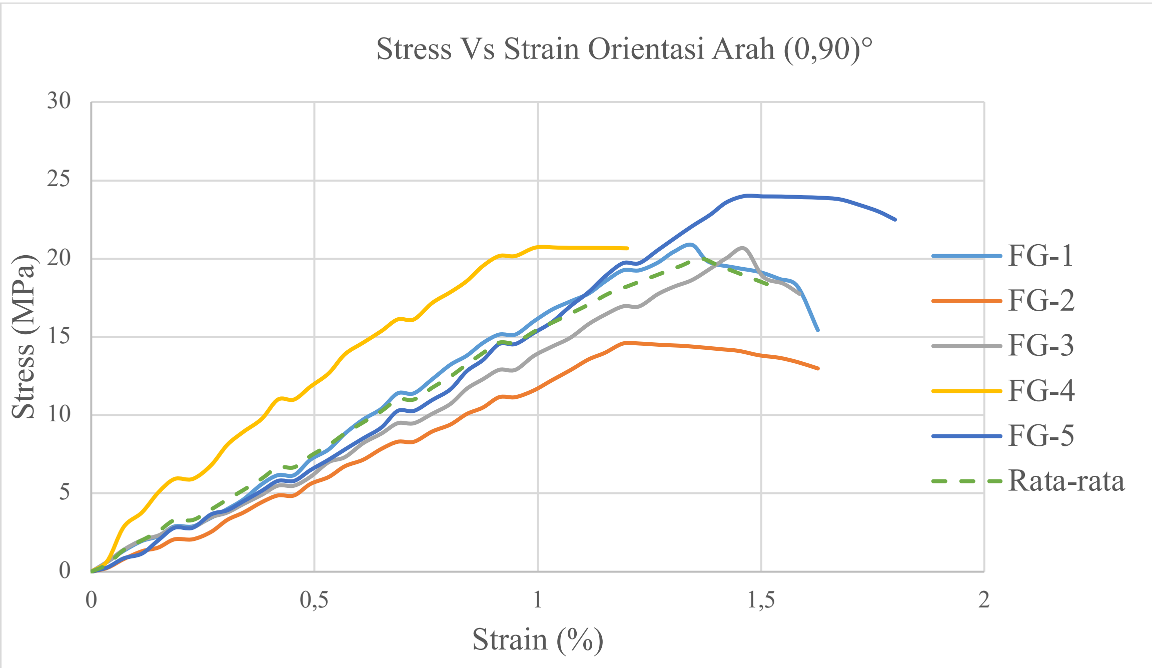


Figure 9. Stress and Strain Graph of E-Glass-Balsa/Polyester Sandwich Composites with Fiber Direction Orientation (0.90)˚

From each data for tensile testing, a graph can be made as shown in Figure 10 for a comparison graph of the tensile strength of carbon-balsa/polyester sandwich composites and e-glass-balsa/polyester sandwich composites based on fiber orientation.

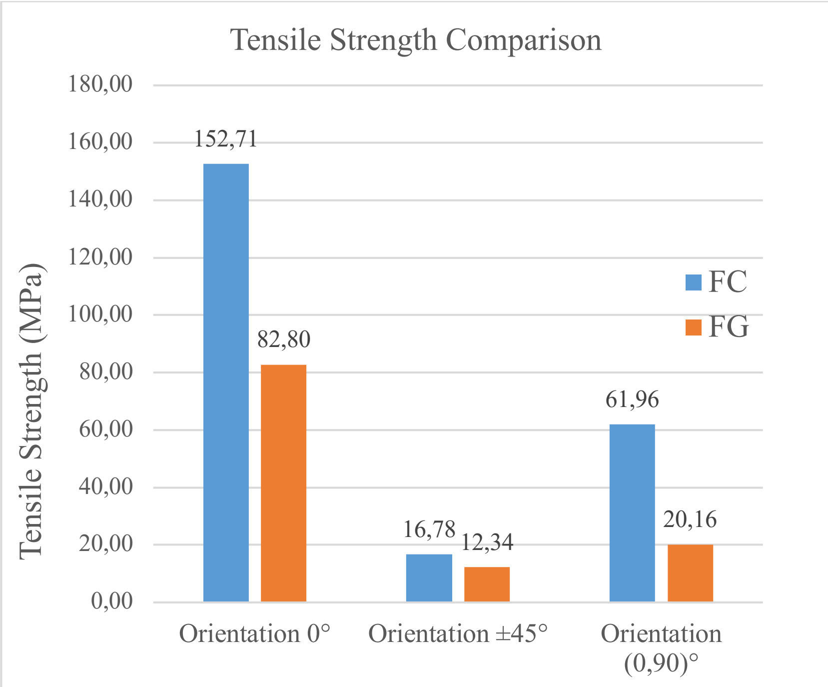


Figure 10. Comparison Graph of Average Tensile Strength of Carbon Fiber-Balsa/Polyester and E-Glass-Balsa/Polyester Sandwich Composites with Fiber Direction Orientation

Based on Figure 10 shows that the carbon-balsa/polyester sandwich composites has the highest tensile strength at 0˚ fiber orientation with a value of 152.71 MPa. Meanwhile, the E-glass-balsa/polyester sandwich composite with a fiber orientation of ±45˚ has the lowest tensile strength with a value of 12.34 MPa. Uneven resin distribution causes voids to form in the specimen, which can affect the tensile strength.

The test results graph shows that the tensile strength of the composite tends to decrease as the fiber direction angle increases. A fiber orientation of 0˚ provides the greatest tensile strength because the fibers are parallel to the loading direction, as well as superior material properties of sandwich carbon-balsa compared to sandwich e-glass-balsa composites. Tables 1 and 2 show the results of the composite density test. Tables 1 and 2 show the results of the composite density test.

Table 1. Density Test Results of Carbon-Balsa/Polyester Sandwich Composites Tensile Test Specimens Based on Fiber Direction Orientation

Fiber Direction Variation	Density (gr/cm^3)
0˚	0,863
±45˚	0,617
(0,90)˚	0,764

The table above shows that the density of the carbon-balsa/polyester sandwich composites with the fiber direction of 0°, ±45°, and (0.90)° has a value of 0.863 gr/cm³, 0.617 gr/cm³, and 0.764 gr/cm³, respectively.

Table 2. Density Test Results of E-Glass-Balsa/Polyester Sandwich Composite Tensile Test Specimens Based on Fiber Direction Orientation

Fiber Direction Variation	Density (gr/cm^3)
0°	0,896
±45°	0,646
(0,90)°	0,758

The table above shows that the density of the E-glass-balsa/polyester sandwich composites with fiber directions of 0°, ±45°, and (0.90)° has a value of 0.896 gr/cm³, 0.646 gr/cm³, and 0.758 gr/cm³, respectively.

The two tables above show that each composite with a fiber direction of 0° has the highest density value, while the fiber direction of ±45° has the lowest density value. Figure 12 shows the failure mode of the tensile test specimen of the carbon-balsa/polyester sandwich composites.

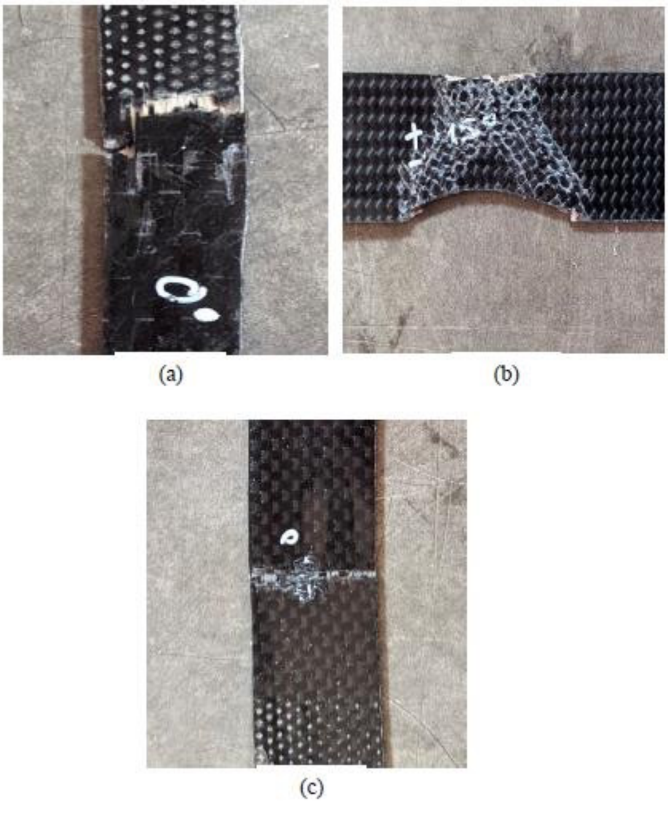


Figure 12. Failure Mode of Carbon-Balsa/Polyester Sandwich Composite Tensile Test Specimens: (a) Orientation 0°, (b) Orientation (0/90)°, and c. Orientation ±45°

Figure 13 shows the failure mode of the tensile test specimen of the E-glass-Balsa/Polyester sandwich composites.

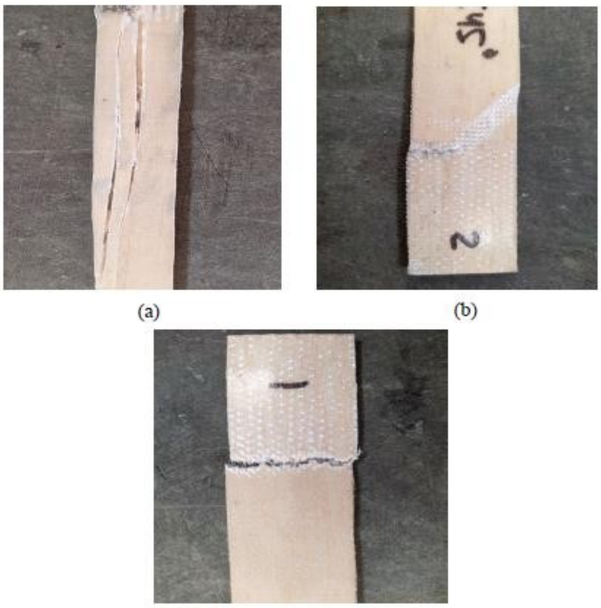


Figure 13. Failure Mode of E-Glass-Balsa/Polyester Sandwich Composite Tensile Test Specimens: (a) Orientation 0°, (b) Orientation (0/90)°, and c. Orientation ±45°

The failure mode that occurs in both types of composites for fiber orientation direction 0, fiber fracture in the same direction as the fiber orientation direction 0°, where the load in the perpendicular direction received by the composite is distributed evenly on the fibers with orientation 0°. As for the fiber orientation direction of (0/90)°, the load received by the fiber is divided into two fiber directions with fiber orientations of 0° and 90° where the load in the perpendicular direction received by the composite is distributed evenly in both fiber directions but the fiber orientation of 0° contributes more to resisting tensile loads. Meanwhile, for the fiber orientation direction of ±45° the load received is distributed evenly in the ±45° direction. So the highest tensile strength of the composite occurs in the fiber orientation direction of 0. The failure mode that occurred in most of the composites was fiber fracture, although some fibers were pulled out of the resin. This shows that the composite manufacturing was quite good.

The results of the study indicate that carbon-balsa/polyester sandwich composites was selected as the spar structure material for the Aero-73K unmanned aerial aircraft / UAV (Unmanned Aerial Vechicle). This composite has the highest tensile strength of 152.71 MPa and a density of 0.863 g/cm^3.

CONCLUSSION

Based on the results of the study concluded that the carbon-balsa/polyester sandwich composites with 0° fiber direction has a greater tensile strength than 0°/90° and ±45° fibers direction. Besides that, it has better mechanical properties when compared to other types of conventional aluminum materials although by using a simple composite hand lay-up manufacturing method but produces a fairly good tensile strength, so it has a good potential to be further developed to be applied to unmanned aerial aircraft / UAV (Unmanned Aerial Vechicle).

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