

STRENGTH ANALYSIS OF COMPOSITE MATERIALS ON CARBON FIBER AND FIBER FIBER WITH TENSILE TEST

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ABSTRACT

In the era of technological advancement, composite materials have become an important cornerstone in modern industry due to their advantages such as light weight, strength, stiffness, and corrosion resistance. The use of carbon fiber and fiber reinforced polymers, especially with catalysts, has successfully overcome the weakness of brittle fracture in composites and provided a solution for high-performance lightweight structures. Previous research shows the tensile strength of the two fibers has an insignificant difference, but the change in layer arrangement significantly affects the elastic modulus value. Therefore, this study aims to analyze the effect of varying the type and number of fibers on the mechanical strength of composites through tensile testing. The research method used analytical methods and ISO-527 standard specimens, with tensile tests on continuously reinforced carbon fiber composites and glass fiber made from Chopped Strand Mat (CSM) type with a ratio of 1011 polymer matrix and catalyst of 10:1. The results show that the different number of carbon fiber layers in the composite has a significant impact on mechanical properties, especially tensile strength. Sample I, with two layers and carbon fiber content, stood out with high tensile strength (100.76 MPa), low maximum strain (1.76%), and superior elastic modulus (5708.4 MPa). The lowest tensile strength value was found in sample IV (19,877 MPa), which consisted of only one layer and was made from carbon fiber. This confirms that the addition of carbon fiber layers significantly improves the mechanical performance of the composite, highlighting the importance of carbon fiber in improving the tensile strength of the composite. Thus, the selection of the best composite material that promotes optimal mechanical strength, the choice falls on carbon fiber with two layers.

Keywords: Carbon fiber, layer, tensile test

1. INTRODUCTION

Technological advances have increased the demand for composite materials and become the foundation of modern industry (Albayrak, M. et al., 2023). Composite materials have advantages over conventional materials such as metals, namely their light weight (Jin, W. et al., 2022), higher strength and stiffness (Balaganesan, G. & Khan, 2026), resistance to corrosion, ability to conduct heat and electricity, and good surface appearance (Tambunan, PP et al., 2022). With these advantages, composite materials are widely used in various sectors as engineering materials such as airplanes, helicopters, satellites, ships, automotive, chemical equipment, sports equipment, building construction and medical equipment (Wahyudi, DT & Ningsih, 2018).

Composite comes from the word to compose, meaning a combination of two or more different materials on a macroscopic scale. This creates a third, more useful material. Composites consist of reinforcement that has less ductile properties but is more rigid and stronger and the matrix is generally more ductile but has lower strength and rigidity (Jones, 1975). The main component in composites is fiber which has many advantages. These fibers can come from nature, such as coconut fiber, pineapple fiber, human hair fiber, and others, or synthetic, such as glass fiber, carbon, aramid, and so on. The use of these fibers in materials aims to increase the strength and durability of the material (Nayiroh, 2013). Fiber-reinforced

composites have different fracture properties than metal materials. Metal materials usually exhibit ductile fracture behavior, which means that the material will experience plastic deformation before breaking. Meanwhile, fiber-reinforced composite materials experience brittle fracture, which will break suddenly without any prior warning signs (Albayrak, M. et al., 2023)

The weaknesses of fiber-reinforced composites have attracted much attention from both academia and industry. The results of the study showed that catalysts can help improve the cohesion properties of the polymer matrix. This can improve the ability of the polymer matrix to resist cracking and delamination. Thus, catalysts can increase the tensile strength, hardness, and impact resistance of the composite (Albayrak, M. et al., 2023). The use of carbon fiber-reinforced polymers (CFRPs) has proven to be able to answer these problems and has been adopted in modern high-performance lightweight structures (Balaganesan, G. & Khan, 2026) . With proper lay-up, these composites have advantages in certain areas (Opelt, CV et al., 2018)

Several previous studies have shown the superiority of carbon fiber composites in terms of tensile strength compared to other fibers (Purnama et al., 2013) . Woven fibers, one of the *continuously reinforced carbon fibers* (Mallick, 2014) . with a 1011 polymer matrix and catalyst has been shown to reduce the fracture properties of the composite. The results of a study conducted by (Wang, X. et al., 2022) woven carbon composites with a 1011 polymer matrix and catalyst showed a 30% increase in impact resistance compared to woven carbon composites with a 1011 polymer matrix without a catalyst. This statement is reinforced by the results of a study by (Albayrak, M. et al., 2023) namely woven carbon composites with a 1011 polymer matrix and catalyst showed a 10% increase in tensile strength and a 20% increase in hardness compared to woven carbon composites with a 1011 polymer matrix without a catalyst.

In addition to the use of carbon fiber as a composite structural reinforcement, fiber fiber also attracts the attention of researchers to find out its advantages. The results of the study (Jesthi, DK et al., 2018) on *hybrid composites of glass (G) and carbon (C) woven fibers* with a number of lamina composite layers of 10 layers and two types of layer arrangement sequences (stacking sequences), it can be concluded that changes in the stacking sequence significantly affect the value of the elastic modulus. Previous studies have confirmed that the critical factor affecting the tensile strength of the composite is the type of reinforcing fiber used (Ichsan, 2015). Recent studies have shown that increasing the number of layers in CFRP composites is in line with increasing tensile strength and elastic modulus values (Abdurohman, K. & Marta, 2016) .

The addition of the top layer to the composite provides significant benefits in increasing the cross-sectional area of the material that can withstand the load, and the regular orientation of the carbon fibers also strengthens the overall strength (Setiawan et al., 2020). An increase in the tensile strength of the composite is also observed along with the increase in the number of layers, which can be attributed to the increase in the contact area between the carbon fibers (Supriyadi et al., nd) Based on the background, material research on carbon fiber and fiber composites through tensile testing was carried out to determine the impact resistance of the composite. Tensile testing is a method to determine the maximum stress and strain capacity of a material. This process is carried out by pulling the material until it reaches a point where the stress and strain reach their maximum value, even to the point of breaking or breaking. The

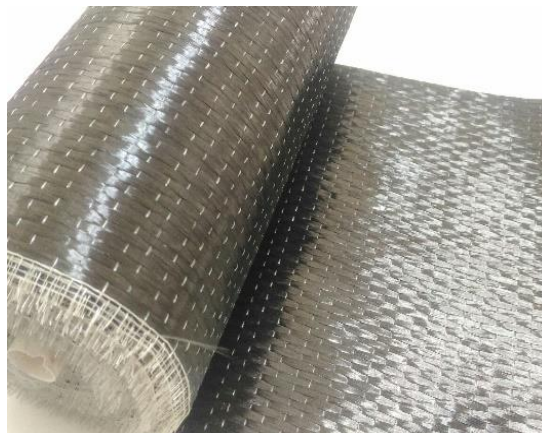
purpose of the tensile test is to understand the material's resistance to tensile force at a certain strength level (Davis, 2004)

1.1. Composite

Composite is also defined as a combination of two or more than three materials that have a number of properties that are impossible to have by each component (Surdia, T. & Chijjiwa, 2000) . The same thing also states that composite is a material formed from a combination of two or more materials, where the mechanical properties and materials that form it are different, then a new material will be produced, namely a composite that has different mechanical properties and characteristics from the materials that form it (Jonathan, O. et al., 2013)

According to (Mott, 2019) composite materials have several advantages and disadvantages. The main advantages include weight reduction, high stiffness-to-strength ratio, adaptability to load settings, better corrosion resistance, and tunable thermal and electrical conductivity. However, there are also disadvantages such as difficulty in bonding composite materials, additional costs for raw materials and fabrication, potential environmental degradation by the matrix, loss of some of the basic properties of the material, challenges in analyzing physical and mechanical properties for damping efficiency, and lack of consensus on physical and mechanical characteristics. However, the economic advantages in manufacturing costs can be an important driving force for the application of composite materials in various applications.

1.2. Carbon Fiber



Source: <https://indonesian.cfrpcarbonfiber.com>

Figure 1. Carbon Fiber Sheet

Carbon fiber is defined as a fiber containing at least 90% carbon through a certain pyrolysis process (Hedge, 2004). Most carbon fibers (about 90%) are made from the polyacrylonitrile (PAN) process. A small amount (about 10%) is made from the petroleum pitch process. To create specific carbon fiber effects and qualities requires a variety of gases, liquids, and other materials. The largest composition in this fiber is called a precursor (raw material) which is used to produce carbon fibers with various shapes and different characteristics.

Carbon fiber can be distinguished based on the precursors used, namely pitch, PAN (poly acrylonitrile), cellulose fibers and certain phenolic fibers. The properties of carbon fiber are as follows (Nurun, 2014) :

1. The density of carbon is quite light, namely around 2.3 g/cc.

2. The graphite structure used to make fiber is shaped like a diamond crystal.
3. It has the characteristics of being light and having very high strength.

The manufacture of carbon fiber goes through mechanical and chemical processes first. Precursors are raw materials that will later be pulled and made into long strands and then heated in a room without anaerobic oxygen. This high temperature makes the atoms of the fiber vibrate so that almost all non-carbon atoms come out. This is called the carbonization process. Later, the remaining fibers consisting of long and tightly interconnected carbon chains, these fibers will be formed into fabric in the weaving process combined with other materials and then collected to be printed or formed into the ordered material.

1.3. Glass Fiber

Glass fiber or commonly called glass fiber is liquid glass that is drawn into thin fibers with a diameter of about 0.005 mm - 0.01 mm. These fibers can be spun into yarn or woven into fabric, which is then impregnated with resin to become a strong and corrosion-resistant material for use as shipbuilding and car bodies. Glass fiber is also used as a reinforcing agent for many plastic products. The resulting composite material is known as glass-reinforced plastic (GRP) or glass-fiber reinforced epoxy (GRE), called fiberglass in common use.

Glass fiber is a non-flammable material. This type of fiber is usually used as a polymer matrix reinforcement. The properties of glass fiber are as follows (Nurun, 2014) :

1. Density is quite low (about 2.55 g/cc)
2. Its tensile strength is quite high (about 1.8 GPa)
3. Usually the stiffness is low (70GPa)
4. Dimensional stability is good
5. The general composition is 50-60% SiO₂ and other alloys namely Al, Ca, Mg, Na, etc.

Based on its shape, glass fiber can be divided into several types, including (Santoso, 2002)

1. Roving, in the form of long threads rolled around a cylinder.
2. Yarn, in the form of thread that is tightly connected to the filament.
3. Chopped Strand Mat (CSM), is a strand that is cut into certain sizes and then combined into one bundle.
4. Reinforcing Mat, in the form of chopped strand and continuous strand sheets arranged randomly.
5. Woven Roving, in the form of long threads that are woven and rolled into a cylinder.
6. Woven Fabric , in the form of fibers woven like woven cloth.
7. The Chopped Strand Mat (CSM) type of glass fiber .

1.4. Polymer

Polymers are large molecules formed from simple repeating units called monomers. The repetition of units (monomers) can form linear, branched and network chains (Stevens, 2001) .

Based on its source, polymers can be divided into two, namely natural polymers such as starch, cellulose and silk produced by plants and animals, other polymers such as synthetic polymers produced in the laboratory. Knowledge of polymer technology continues to grow, because currently we are not aware that in everyday life we have used polymer materials ranging from clothing, household appliances to airplanes. This is done to replace metal and

ceramic materials because some of the advantages of polymer materials are light, easy to shape, resistant to corrosion, cheap and low production costs.

1.5. Stress and Strain Analysis and Elastic Modulus

Stress is defined as the intensity of force per unit surface area where the force acts (Gere et al., 2000). In general, stress is divided into two, namely normal stress and shear stress. Normal stress is stress caused by a force acting perpendicular to the surface area of an object .

$$\sigma = \frac{F}{A}$$

Information:

σ = Normal stress (N /m²)

F = Normal force (N)

A = Surface area of the object where the force works parallel to the surface of the object (m²)

While shear stress is stress caused by shear forces acting parallel to the surface area of an object.

$$\tau = \frac{V}{A}$$

Information:

τ = Shear stress (N/m²)

F = Shear force (N)

A = Surface area of the object where the force works parallel to the surface of the object (m²)

When an object is given a force, tension will occur in the elements of the object. The tension that occurs will cause strain. Strain is defined as the ratio between the change in length and the initial length of an object.

Strain is divided into two, namely normal strain and shear strain. The strain value can be determined by the following equation (Hutahean, 2014):

$$\varepsilon = \frac{\Delta L}{L_o} = \frac{L - L_o}{L_o}$$

Information :

ε = Strain (%)

ΔL = Deformation/elongation (mm)

L_o Initial length (mm)

L = Final length (mm)

In the section the increase in length is proportional to the increase in the load given. In this section, Hooke's law applies:

$$\Delta L = \frac{P}{A} \times \frac{L_o}{E}$$

Information :

ΔL = Deformation/elongation (mm)

L_o Initial length (mm)

L = Final length (mm)

P = Working load (N)

A = cross-sectional area of the workpiece (mm^2)

E = Modulus of elasticity of the material (N/mm^2)

The magnitude of the composite elastic modulus, which is also the ratio between stress and strain in the proportional region, can be calculated using the following equation :

$$E = \frac{\sigma}{\varepsilon}$$

Information :

E = Modulus of elasticity (N/mm^2)

σ = Stress (N/mm^2)

ε = Strain (%)

$$G = \frac{\tau}{\gamma}$$

Information:

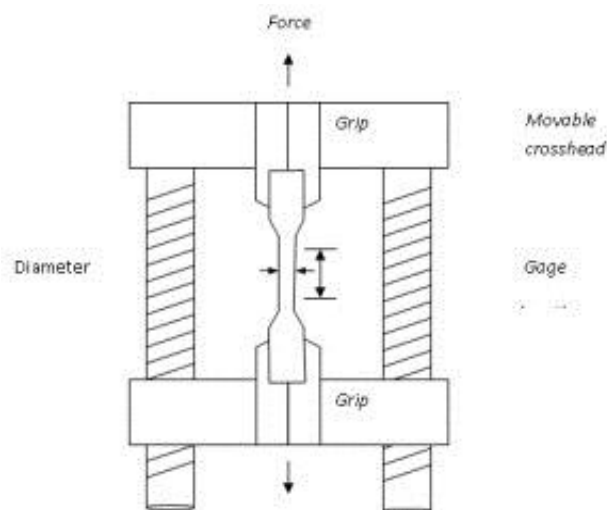
G = Shear modulus (N/m^2)

τ = Shear stress (N/m^2)

γ = Shear strain

1.6. Tensile Test

Tensile testing is a method used to test the strength of a material by providing a uniaxial force load (Askeland et al., 2010) . The results obtained from tensile testing are very important for product design and engineering because they produce data . material strength. Tensile testing is used to measure the resistance of a material to static forces applied slowly. The tensile testing scheme can be seen in Figure 2.



Source: <https://sersasih.files.wordpress.com/2011/07/untitled.jpg>

Figure 2. Tensile Test Scheme

The tensile strength of composites is influenced by several factors, including:

1. Temperature

If the temperature increases then the tensile strength will decrease.

2. Humidity

The effect of humidity can result in increased water absorption, which will result in increased fracture strain. While the fracture stress and elastic modulus decrease.

3. Voltage Rate

If the stress rate is small, then the elongation increases and causes the stress-strain curve to become flat, the elastic modulus is low. While if the stress rate is high, then the fracture load and elastic modulus increase, but the strain decreases.

4. Big Stretch

The magnitude of the strain is the amount of increase in length due to loading compared to the length of the measuring area (*gage length*). This strain value is a proportional strain obtained from the proportional line on the stress-strain graph.

Composite tensile testing was carried out using the composite tensile test method using the ASTM D638-02a standard.

This study aims to analyze the effect of fiber type and number of fiber variations on the mechanical strength in the form of tensile strength in composite materials. The main focus of the study is to compare continuously reinforced carbon fiber with Chopped Strand Mat (CSM) type fiber in tensile tests, and to evaluate how the type and number of fibers affect the mechanical properties of the material. In addition, this study also aims to observe the application of the theory that has been studied with field conditions, evaluate the quality of materials in mass products, and assess the results of tensile tests on carbon fiber and fiber composite materials as a comparison.

2. RESEARCH METHODOLOGY

2.1. Research Design

Based on Figure 3, the steps taken to investigate the effect of variations in layer composition on the tensile strength of carbon fiber and fiber composites reinforced continuously with *epoxy resin* and catalyst are systematically described as follows:

1. Literature study

Searching for theoretical frameworks and previous studies on composites, carbon fiber, glass fiber, polymers, laminate failure modes, physical properties of composites, and tensile tests.

2. Preparation

a. Selection of Test Materials:

Test materials are selected based on research objectives, namely:

- Continuously reinforced carbon fiber
- Chopped Strand Mat (CSM) type glass fiber
- Epoxy resin 1011
- Catalyst

b. Testing Method Selection:

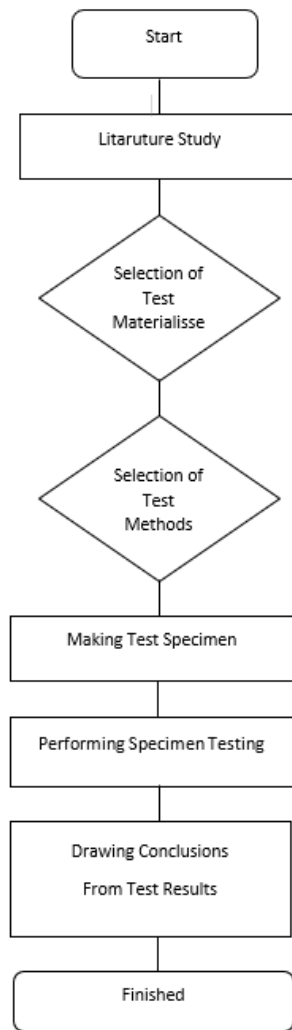
The test method is selected based on the mechanical properties to be measured, namely: u static tensile test according to ASTM D638

c. Tool Preparation:

The tools needed for making and testing specimens are prepared, namely:

- Universal Testing Machine (UTM)
 - Digital scales
 - Ruler or vernier caliper
 - Measuring cup
 - Scissors
 - Sandpaper
 - Mixer
 - Paintbrush
3. Specimen Preparation
 - a. Specimens were prepared following established procedures.
 - b. The dimensions and thickness of the specimen must comply with the standards used.
 - c. Ensure that the specimen is free from defects that could affect the test results.
 - d. Specimens as test tools consist of:
 - Sample I: Two sheets of continuously reinforced carbon fiber coated with resin and catalyst. Dimensions: 25 cm x 2.5 cm x 0.3 cm.
 - Sample II: One sheet of continuously reinforced carbon fiber coated with resin and catalyst. Dimensions: 25 cm x 2.5 cm x 0.1 cm.
 - Sample III: Two sheets of Chopped Strand Mat (CSM) type glass fiber coated with resin and catalyst. Dimensions: 25 cm x 2.5 cm x 0.2 cm.
 - Sample IV: Two sheets of Chopped Strand Mat (CSM) type glass fiber coated with resin and catalyst. Dimensions: 25 cm x 2.5 cm x 0.15 cm.
 4. Testing
 - a. Testing was carried out on a Universal Testing Machine (UTM) following the procedures set out in the ASTM D638 standard.
 - b. Measuring tensile strength, elastic modulus, and strain
 - c. The test results data are recorded carefully.
 5. Data analysis
 - a. The test result data was analyzed using appropriate statistical methods.
 - b. The results of data analysis are interpreted and presented in the form of tables, graphs, or images.
 6. Conclusion

Drawing conclusions about the influence of fiber type and number of layers on the mechanical properties of composites.



Source: Processed data, 2023

Figure 3. Research Flow Chart

2.2. Data Collection Procedure

Test specimen sample with the tensile test type according to ASTM D638. This standard is intended to follow the international testing level to obtain good and accurate mechanical properties.

The following is the specimen testing procedure:

1. Measurements were made using a ruler/vernier caliper to obtain the length, width and thickness of the test sample at several sample points.
2. Perform the test machine settings on the personal computer, for test speed set to 5.0 mm/min, initial sample length distance set to 115 mm, and input the specimen dimensions.
3. The sample is clamped by the jig of the tensile testing machine and then check the straightness of its axis.
4. Check the sample holder to prevent slipping during testing.
5. Press the on button on the testing machine for the sample withdrawal process until failure or breakage occurs.

6. Repeat the above steps for samples II, III and IV. The tensile test can be seen in Figure 22.

3. RESULTS AND DISCUSSION

3.1. Tensile Test

Tensile testing is intended to obtain the tensile stress value of a test material. The specimens to be tested consist of four samples, namely:

1. Sample I: A two-layer carbon fiber sheet coated with a mixture of resin and catalyst .
2. Sample II: A single-layer carbon fiber sheet coated with a mixture of resin and catalyst.
3. *Chopped Strand Mat (CSM)* type glass fiber sheet coated with a mixture of resin and catalyst .
4. *Chopped Strand Mat (CSM)* type glass fiber coated with a mixture of resin and catalyst.

Then the four samples were measured and cut according to the ISO-527 standard. It is expected that after this test the difference in tensile strength of the three samples will be known.

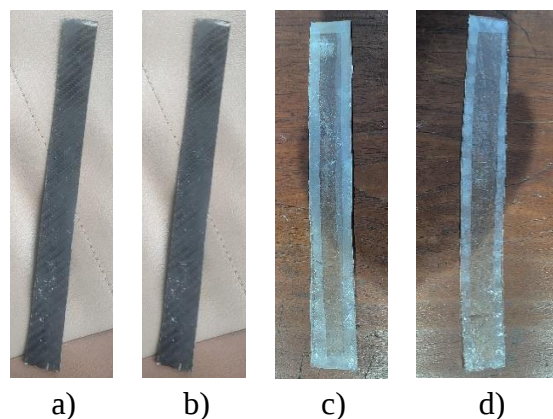


Figure 4. 1a) Sample I Ready for Testing; b) Sample II Ready for Testing ; c) Sample III Ready for Testing ; Sample IV Ready for Testing

3.2. Sample Tensile Test I

Table 1. Results of Tensile Test of Sample I

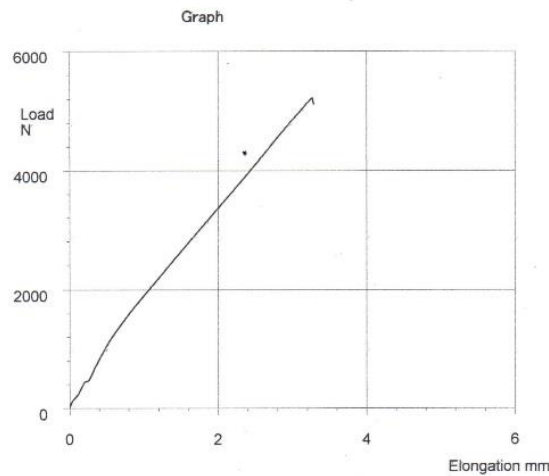
Width (mm)	Thickness (mm)	Sectional ar (mm ²)	Maximum Point Load (N)	Maximum Point Stress (MPa)	Elastic Modulus (MPa)
24.170	2.1400	51,724	5211.5	100.76	5708.4

Source: BKI Laboratory, 2024

Table 1 presents the tensile test results for Sample I. The test specimen has a width of 24.170 mm and a thickness of 2.1400 mm. The cross-sectional area of the specimen, expressed in Sectional Area, is 51.724 mm². During the tensile test, the specimen is loaded to a maximum point load of 5211.5 N, and at that point, the maximum stress reaches 100.76 MPa. The modulus of elasticity of the specimen, which measures its ability to recover its shape after elastic deformation, is measured at 5708.4 MPa (testing based on ISO-527 standard and in a room temperature of 27.2 °C).

Figure 5 shows that after being given a tensile load, sample I experienced fracture. at the bottom. The tensile strength of composite sample I consisting of two layers coated with a

mixture of resin and catalyst is 100.76 MPa is the maximum stress of the specimen until it breaks with a maximum strain of 1.76% so that the elastic modulus value is 5708.4 MPa.



Source: BKI Laboratory, 2024

Figure 2Results of Tensile Test of Sample I

The maximum strain is obtained from the following calculation:

$$\varepsilon = \sigma/E$$

Where:

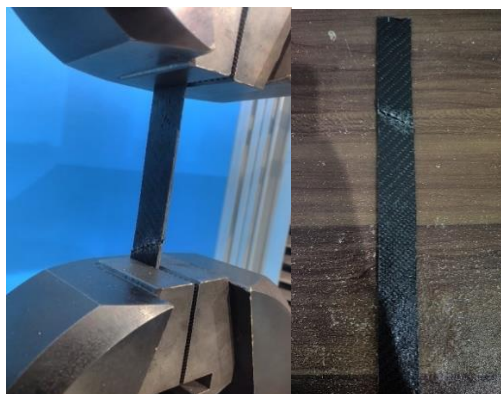
σ = tension,

E = modulus of elasticity, and

ε = strain.

$\varepsilon = 100.76 \text{ Mpa} : 5708.4 \text{ Mpa}$

$\varepsilon = 0.0176$



Source: BKI Laboratory, 2024

Figure 6. Fracture of Sample I after Tensile Test

3.3.Sample Tensile Test II

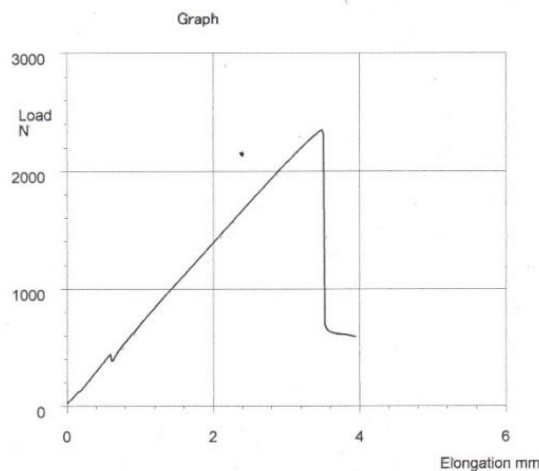
Table 2 presents the tensile test results for Sample II. This test specimen has a width of 25,160 mm and a thickness of 1.0000 mm. The cross-sectional area of the specimen, expressed in Sectional Area, is 25,160 mm². During the tensile test, the specimen withstands loading up to a maximum point load of 2347.9 N. At that point, the maximum stress experienced by the

specimen reaches 93.317 MPa. The modulus of elasticity of the specimen, which measures its ability to recover its shape after elastic deformation, is measured at 3380.0 MPa.

Table 2. Results of Tensile Test of Sample II

Width (mm)	Thickness (mm)	Sectional ar (mm ²)	Maximum Point Load (N)	Maximum Point Stress (MPa)	Elastic Modulus (MPa)
25.160	1.0000	25.160	2347.9	93,317	3380.0

Source: BKI, 2024



Source: BKI Laboratory, 2024

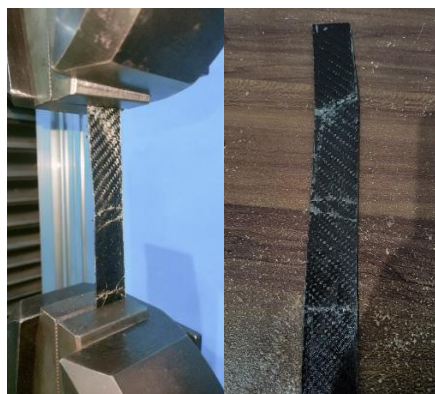
Figure 7. Results of Tensile Test of Sample II

Figure 7 shows that after being given a tensile load, sample II experienced fracture. in the middle and bottom. The tensile strength of composite sample II consisting of one layer coated with a mixture of resin and catalyst is 93,317 MPa which is the maximum stress of the specimen until it breaks with a maximum strain of 2.76% so that the elastic modulus value is 3380.0 MPa. The maximum strain is obtained from the following calculation:

$$\varepsilon = \sigma/E$$

$$\varepsilon = 93.317 \text{ MPa} : 3380.0 \text{ MPa}$$

$$\varepsilon = 0.0276$$



Source: BKI Laboratory, 2024

Figure 8. Fracture of Sample II After Tensile Test

3.4. Sample Tensile Test III

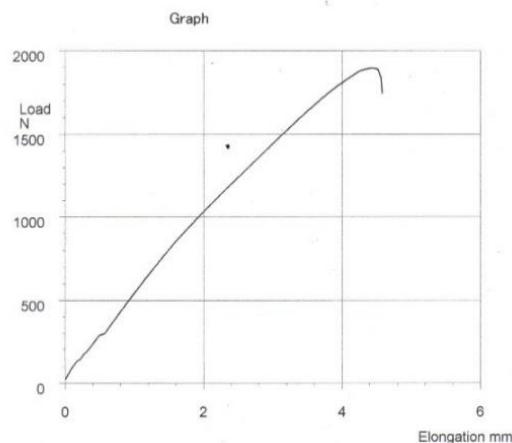
Table 3. Results of Tensile Test of Sample III

Width (mm)	Thickness (mm)	Sectional ar (mm ²)	Maximum Point Load (N)	Maximum Point Stress (MPa)	Elastic Modulus (MPa)
29,970	2.3000	66,701	1892.1	27,541	1273.1

Source: BKI, 2024

Table 3 presents the tensile test results for Sample III. The test specimen has a width of 29,970 mm and a thickness of 2,3000 mm. The cross-sectional area of the specimen, expressed in Sectional Area, is 66,701 mm². During the tensile test, the specimen is loaded to a maximum point load of 1892.1 N, and at that point, the maximum stress reaches 27,541 MPa. The modulus of elasticity of the specimen, which measures its ability to recover its shape after elastic deformation, is measured at 1273.1 MPa (testing based on ISO-527 standard and in a room with a temperature of 22.1 °C).

Figure 9 shows that after being given a tensile load, specimen III experienced fracture. at the bottom. The tensile strength of the composite made of fiber sample III consisting of two layers coated with a mixture of resin and catalyst is 27,541 MPa is the maximum stress of the specimen until it breaks with a maximum strain of 2.16% so that the elastic modulus value is 1273.1 MPa.



Source: BKI, 2024

Figure 9. Results of Tensile Test of Sample III

The maximum strain is obtained from the following calculation:

$$\varepsilon = \sigma/E$$

$$\varepsilon = 27,541 \text{ MPa} : 1273.1 \text{ MPa}$$

$$\varepsilon = 0.0216$$

3.5. Sample Tensile Test IV

Table 4 presents the tensile test results for Sample IV. The test specimen has a width of 29,970 mm and a thickness of 1,4700 mm. The cross-sectional area of the specimen, expressed in Sectional Area, is 44,056 mm². During the tensile test, the specimen was loaded to a

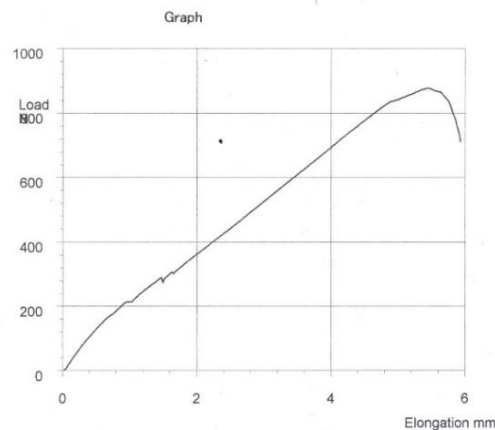
maximum point load of 875.70, and at that point, the maximum stress reached 19,877 MPa. The modulus of elasticity of the specimen, which measures its ability to recover its shape after elastic deformation, was measured at 1017.7 MPa (testing based on ISO-527 standard and in a room temperature of 22.1 °C).

Table 4. Results of Tensile Test of Sample IV

Width (mm)	Thickness (mm)	Sectional ar (mm ²)	Maximum Point Load (N)	Maximum Point Stress (MPa)	Elastic Modulus (MPa)
29,970	2.3000	66,701	1892.1	27,541	1273.1

Source: BKI, 2024

In Figure 10 it can be seen that after being given a tensile load, the specimen fractured. at the bottom. The tensile strength of composite sample IV consisting of one layer coated with a mixture of resin and catalyst is 19,877 MPa is the maximum stress of the specimen until it breaks with a maximum strain of 1.95% so that the elastic modulus value is 1017.7 MPa.



Source: BKI Laboratory, 2024

Figure 10. Tensile Test Results of Sample IV

The maximum strain is obtained from the following calculation:

$$\varepsilon = \sigma/E$$

$$\varepsilon = 19.877 \text{ MPa} : 1017.7 \text{ MPa}$$

$$\varepsilon = 0.0195$$

3.6.Comparison of Tensile Test of Sample II (Carbon Fiber) and Sample IV (Fiber Fiber) with One Layer

Comparison between Sample II (using carbon fiber, 1 layer) and Sample IV (using fiber, 1 layer) in tensile test revealed significant differences in the mechanical properties of both. Although both have the same number of layers and were subjected to similar types of tests, the results show striking differences as presented in Table 5.

In terms of tensile strength, Sample II shows a significant advantage with a tensile strength 4.7 times higher than Sample IV. This indicates that carbon fiber has a much higher capacity to withstand tensile loads than fiber. In addition, Sample II also displays a maximum strain of

41.54% higher than Sample IV, indicating that carbon fiber has the ability to stretch longer before failure.

Table 5. Comparison of Mechanical Properties of Samples II and IV

Mechanical Properties	Sample II (Carbon Fiber)	Sample IV (Fiber)	Difference (%)
Tensile strength (MPa)	93,317	19,877	78.63
Maximum strain (%)	2.76	1.95	41.54
Modulus of elasticity (MPa)	3380	1017.7	70.19

Source: Data processed by researchers, 2024

When considering the elastic modulus, Sample II also shows a much higher stiffness, 3.33 times higher than that of Sample IV. This indicates that carbon fiber is more resistant to deformation than glass fiber.

These differences stem from the intrinsic properties of each type of fiber. Carbon fiber, with its high tensile strength, elastic modulus, and deformation ability, is suitable for applications that require superior mechanical performance such as automotive components, sporting goods, and aircraft structures. On the other hand, fiberglass, despite its lower cost and corrosion resistance, is better suited for applications where strength and stiffness are not as high, such as vehicle body panels, storage tanks, and pipes.

3.7. Comparison of Tensile Test of Samples I (Carbon Fiber) and III (Fiber Fiber) with Two Layers

The main difference between sample I and sample III is the fiber used. Sample I consists of 2 layers and is made of carbon fiber, while sample III which also consists of two layers is made of glass fiber type *Chopped Strand Mat* (CSM). The difference in the basic fiber material in the two samples causes differences in several mechanical properties of the composite as presented in Table 6.

Table 6. Comparison of Mechanical Properties of Samples I and III

Mechanical Properties	Sample I (Carbon Fiber)	Sample III (Fiber)	Difference (%)
Tensile strength (MPa)	100.76	27,541	72.64
Maximum strain (%)	1.76	2.16	22.73
Modulus of elasticity (MPa)	5708.4	1273.1	77.73

Source: Data processed by researchers, 2024

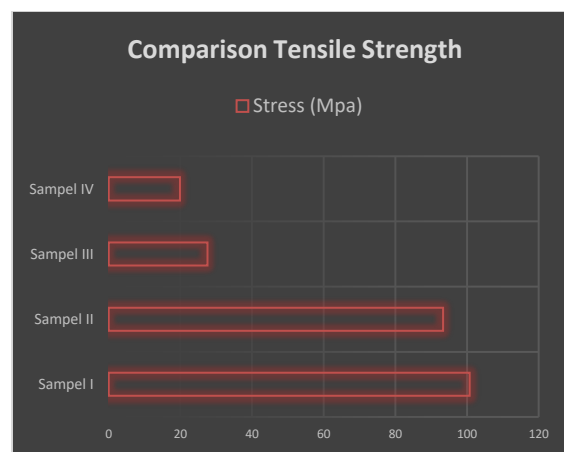
The significant difference in mechanical properties between Sample I (carbon fiber) and Sample III (fiber) shows the substantial impact of the different types of fibers used in the composite. In terms of tensile strength, Sample I shows a striking advantage with a tensile strength 3.66 times higher than Sample III, indicating that carbon fiber has a much higher capacity to withstand tensile loads.

Despite having a lower tensile strength, Sample III showed a maximum strain 22.73% higher than Sample I, indicating the ability of the fiber to stretch to a greater length before failure. However, when considering the elastic modulus, Sample I stood out with a stiffness 4.48 times higher than Sample III, indicating that the carbon fiber is much more resistant to deformation.

These differences provide a deeper understanding of the potential applications of each type of composite. Sample I, which relies on carbon fiber, is suitable for applications requiring high tensile strength and stiffness, such as aircraft structures, automotive components, and sports equipment. On the other hand, Sample III with its glass fiber is more suitable for applications that consider cost factors, greater deformation ability, and corrosion resistance, such as vehicle body panels, storage tanks, and pipes.

3.8. Discussion of Tensile Test Results

Figure 11 It can be seen that the difference in fiber type and number of fibers in the test object can affect the tensile strength value. It can be seen that the lowest tensile strength value is in sample IV, which only consists of one layer and is made of fiber. The strength increases when the composite is added with a second layer and is made of carbon fiber (sample I).



Source: Data processed by researchers, 2024

Figure 11 . Tensile Strength Comparison Diagram

The results of the study showed that carbon fiber can significantly increase the tensile strength of the composite compared to *Chopped Strand Mat* (CSM) type glass fiber . This is due to the nature of carbon fiber which has a high *specific modulus* and *specific strength* , as well as good adhesion to epoxy resin (Purnama et al., 2013)

The results of this study are in line with previous research (Supriyadi et al., nd) which concluded that the effect of the number of layers on the greatest tensile strength occurs when the number of layers in the composite increases, because the increasing number of layers or the

increasing volume fraction in the material increases the tensile strength. Other studies have also found that the highest tensile strength is obtained in the top 3 layers of carbon composites (Setyawan *et al.* , 2020).

(Schwartz, 1984) stated that the fiber factor is one of the factors that affect the properties of the composite. Carbon fiber has a very high tensile strength, which is around 1500 MPa. This tensile strength is much higher than the tensile strength of metal materials, such as steel (200 MPa) and aluminum (70 MPa). In a composite with 2 layers of carbon fiber, there are two layers of carbon fiber that are parallel to each other. The first layer of carbon fiber will withstand the tensile load acting on the composite. The second layer of carbon fiber will help strengthen the composite and prevent cracking. Therefore, the use of carbon fiber in composites can significantly increase the tensile strength of the composite. This supports research that states that the direction of carbon fiber affects the mechanical properties of the composite in this study. Nazarrudin (2022) stated that the direction of carbon fiber parallel to the tensile load (0°) produces greater tensile strength (1500 MPa) compared to the 45° fiber direction, because carbon fiber absorbs the tensile load directly.

4. CONCLUSION

Based on the results of the research conducted, several conclusions can be drawn. This study refers to the tensile test standard ISO-527. Among the tested samples, Sample I, composed of two carbon fiber layers, demonstrated the highest tensile strength (100.76 MPa) and elastic modulus (5708.4 MPa), making it highly suitable for applications that require superior strength and stiffness, such as aircraft structures and automotive components. Sample II, with a single carbon fiber layer, also exhibited good tensile strength (93.317 MPa), high ultimate strain (2.76%), and a moderate elastic modulus (3380 MPa), making it appropriate for applications requiring strong mechanical performance like automotive parts and sports equipment. Meanwhile, Sample III, which used two fiber layers, showed lower tensile strength (27.541 MPa) and modulus (1273.1 MPa), but greater deformation capability, making it suitable for corrosion-resistant applications such as vehicle body panels. Sample IV, with only one fiber layer, had the lowest tensile strength (19.877 MPa) and modulus of elasticity (1017.7 MPa), but offered cost efficiency, thus fitting for corrosion-resistant applications like storage tanks and piping systems. Furthermore, from the testing results, only Sample I experienced a single-point fracture, while Samples II, III, and IV fractured at multiple points. The research also shows a clear relationship between fiber type and the number of layers with the resulting tensile strength, where carbon fiber consistently outperformed standard fiber, and increasing the number of fiber layers led to improved strength. Ultimately, for optimal mechanical strength, the best material choice falls on two-layered carbon fiber composites. Based on the results of the research that has been conducted, the following conclusions can be drawn:

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