International Journal of Marine Engineering and Applications
Volume 2, Number 2, September 2025
e-ISSN: 3063-640X

Date of Received: September 17, 2025
Date of Accepted: September 25, 2025
Date of Published: September 30, 2025
DOI: doi.org/10.30649/ijmea.v2i2.394

MATERIAL DURABILITY ANALYSIS ON FIBERGLASS SHIP CONSTRUCTION

Fariz Maulana Noor[1*]

[1] Hydrodynamics Technology Research Centre, National Research and Innovation Agency, Indonesia

*Corresponding Author: farizmaulana@gmail.com

ABSTRACT

Industrial needs for materials that have the same properties as metals and are resistant to corrosion require the development of various types of materials, one of which is fiberglass composite. The use of fiberglass material has been widely used in the automotive, shipping, and other industries. This research aims to analyze the strength of materials on fiber ships to identify the characteristics of FRP composite materials used on fiber ships. The method used in this research is to conduct material strength testing on FRP composite samples using tensile testing techniques to predict material strength on fiber ships. The results of the study are the highest tensile strength value, namely the volume fraction of 40%, namely 198.99 Mpa and the smallest tensile strength value at a volume fraction of 20% and the effect of tensile volume on tensile strength, where the greater the percentage of the volume fraction value, the greater the tensile strength value of the composite range from 20% to 40%. The conclusion in this study is that there is an effect of tensile volume on tensile strength, where the higher the percentage of volume fraction value, the higher the tensile strength value of the composite and in the test specimen almost debonding or fiber pull out, which occurs due to the selection of the manufacturing method, namely hand lay-up which is likely to occur voids in composite specimens.

Keywords: Endurance, fiberglass, materials, tensile test

Introduction

A fiber ship is one type of ship made of a fiber-reinforced plastic (FRP) composite material, which offers high strength and durability. Because fiber ships are made of composite materials, material strength analysis is critical to ensure the safety and reliability of the ship when operating at sea.

The use of composite materials, especially fiberglass, is already familiar in the shipping industry in Indonesia [1]. Fiberglass material is still the main choice for fishing boats, because regulations in Indonesia do not allow the use of wood raw materials as the basic material for shipbuilding, so fiberglass material is the main choice besides aluminum and steel [2].

The implementation of laminated fiberglass ship construction until now is still a special focus of both practitioners and academics, where the thickness of the laminated layer does not guarantee that a fiberglass ship construction will be strong. Therefore, vulnerability in the hull construction section is a technological problem that must be solved [3].

Making fiberglass is not too difficult. The main material consists of three parts, namely fiber, resin, and catalyst [4]. This research intends to determine the strength, toughness, and hardness of fiberglass material based on fiber pattern variations by maintaining the composition of resin and catalyst.

This research aims to conduct a material strength analysis on fiber ships to identify the characteristics of FRP composite materials used in fiber ships, and evaluate the performance of fiber ships in terms of strength and resistance to external loads such as water pressure and ocean waves. The method used in this research is to conduct material strength testing on FRP composite samples using tensile testing techniques to predict material strength on fiber ships.

The BKI Rules (1996 and 2009) do already include technical rules in ship building, but they still adopt the rules in foreign classification rules, where the basic water conditions used are different from the water conditions in Indonesia, which are relatively calm. Thus, rules on fiberglass ships still need to be refined and adapted to the conditions of Indonesian waters. Material usage standards are based on specimen test results (tensile strength, bending strength, and fiber content) according to the BKI 2006 rules. There are many types of -nonmarine grade|| fiberglass materials on the market at low prices, which are basically for use in making chairs, water tanks, children's toys, and others. Limited understanding and knowledge of the shipyard can result in the use of materials that are wrong and unqualified for use in shipbuilding. Some types of glass fiber and resin are on the market. Types of glass fibers in the local market include WR (Woven Roving), CSM (Chopped Strand Mat), and multiaxial of various sizes [4].

The results of this study are expected to provide a clear picture of the characteristics of FRP composite materials on fiber ships and also provide important information about the performance of fiber ships in terms of strength and resistance to external loads. This information can be a reference for ship companies to improve the quality and performance of their fiber ships, as well as maintain the safety of the ship and the crew working on it.

Thus, this material strength analysis research on fiber ships is expected to contribute to the development of ship technology and improve safety in the operation of fiber ships at sea.

However, there are still not many case studies to analyze material durability in fiberglass ship construction. So as to know the strength, toughness, and hardness. Therefore, in this case study, the analysis of material resistance in fiberglass ship construction. In this study, the authors developed a variety of fiber patterns by maintaining the composition of resin and catalyst.

Methodology

The method used in this research is to conduct material strength testing on FRP composite samples using tensile testing techniques to predict material strength on fiber ships. For data collection by means of field observations and literature studies. For model design as follows:

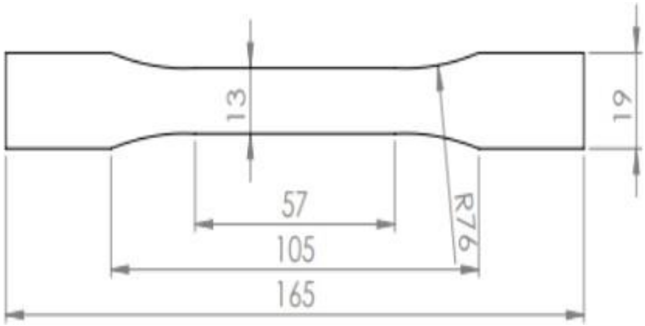

Figure 1. Model design

a. Model Sample

The sample making process uses the hand lay-up technique, where the sample is made with fiberglass fiber chopped standard mat and woven roving with fiber variations of 20%, 25%, 30%, 35%, 40%, 50%, 60%. The hand lay-up technique is one of the composite manufacturing. The process involves the manual placement of glass fiber (fiberglass) layers and impregnation with resin. First step: Place the first layer of glass fiber on a mold that has been coated with a separating agent. Then, apply resin using a brush or roller until the entire surface of the glass fiber is impregnated with resin.

Figure 2. Specimen: (a) CMS, (b) WR

Repeat this process for subsequent layers until the desired thickness is reached (Figure 1). Ensure that each layer of glass fiber (Figure 2) is well impregnated with resin and that no air bubbles are trapped. The advantages of this technique do not require sophisticated equipment and can be done at a relatively low cost; it can be used for a variety of mold shapes and sizes, and the operator has full control over the amount of resin and fiber placement, allowing customization according to specific needs. However, product quality is highly dependent on the skill and experience of the operator; it is difficult to achieve consistent resin thickness and distribution, and the process can take longer than other, more automated techniques.

(a)

(b)

Figure 3. Tools and materials: (a) universal testing machine, (b) digital scales

b. Tools and Materials

In this study, several tools and materials are needed for testing purposes. Tools and materials used, such as a universal testing machine (UTM), a universal testing machine is mechanical devices used to perform a wide variety of tests on materials, including tensile tests, compression tests, bending tests, and more. Specimen molds are an important tool in the fiberglass composite manufacturing process, as they determine the shape, size, and final quality of the composite product. In the hand lay-up technique, molds are used to hold the glass fibers and resin during the forming and hardening process. Digital scales are an essential tool in the process of making fiberglass composites using the hand lay-up technique. The main function of digital scales is to measure the weight of resin and other chemicals with high accuracy, ensuring the right ratio between components, which is crucial for the quality and consistency of the resulting composite tools and materials, as shown in Figure 3.

Collection techniques and data processing, and analysis. The research data is obtained from the results of tensile testing, and an analysis of the test results is carried out.

c. Tensile Test

Tensile testing is done to find stress and strain (stress-strain test). From this test, we can know some of the mechanical properties of materials that are needed in engineering design. The result of this test is a graph of load versus elongation. Load and elongation can be formulated (Eq.1 and Eq.2):

$$\sigma = \frac{F}{A_0} \tag{1}$$

where:

F = Load applied in the direction perpendicular to the cross section of the specimen (N)

A_0 = Initial cross-sectional area of the specimen before loading (m^2)

Σ = Engineering Stress (MPa)

$$\varepsilon = \frac{l_1 - l_0}{l_0} = \frac{\Delta L}{l_0} \tag{2}$$

ε = Engineering strain

l_0 = Initial length of specimen before loading (m)

ΔL = Length gain (m)

Tests are carried out by tensile testing of the matrix (plastic resin type) and the composite, using the JIS K 7113 (1981) testing standard (Annual Book of JIS Standards, K 7113, 396-407). Prepare a fiber with a minimum length of 10 cm according to

the test standard. After that, make the paper shape, but in the middle, it is not broken. The tensile test specimen is placed between the paper then the end of the fiber is glued to the paper with adhesive glue. The purpose of sticking the fiber in the paper is so that the tensile load is only held by the fiber, so that the fiber retaining sheet only functions to hold the fiber, so that it does not slip with the clamp. After the paper sheet is clamped in the fiber tensile testing machine chuck, the fiber retaining sheet is cut, so that the tensile load is only held by the fiber. Once ready, the test was carried out. The specimen is pulled until it breaks, and the load is recorded so that the tensile strength can be calculated and the maximum value.

d. Pull-Out Fiber Test

The tools and materials used for the pull-out fiber test include a single fiber with a predetermined length of at least 20 cm, a small pipe with a diameter of ½ inch with a length of 3 cm, epoxy resin mixed with catalyst in a ratio of 100: 1 flat plate as a foundation, support pole so that the fiber can stand upright, fiber testing machine. universal with a maximum load of 10 kg, and adhesive glue.

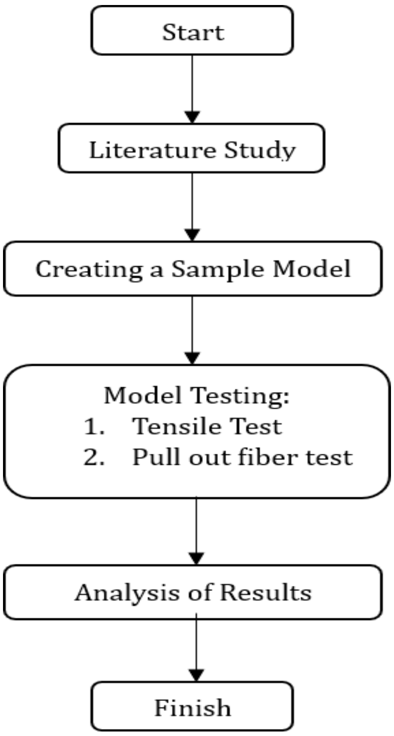

Figure 4. Flow chart

The initial step for working on the pull-out fiber test is to prepare a fiber with a minimum length of 20 mm that has been determined. Then, a small pipe that has been cut in a mold is placed on a flat plate with adhesive glue at the bottom of the pipe so that the epoxy resin does not leak. Tie the fiber to the support pole. Mix the matrix according to the dosage. Insert the fiber into the hole that has been made in the pipe with a fiber depth of 5 mm, 7 mm, respectively. After that, pour the matrix mixture into the prepared pipe mold where the fiber has been inserted first. Try to keep the mold surface parallel to the poured resin. Place the specimen with the print on a flat surface, so that the position of the fiber can be perpendicular so that there is no tilt with the plate.

Wait for this condition for 8-12 hours or until the resin has completely dried. After all is done, pull-out fiber tests are carried out with a universal fiber testing machine with a maximum load of 10 kg.

After pull-out fiber tests are carried out, the critical length results will be obtained, and the fiber can be pulled out at a predetermined depth. This critical length is used as data for making composite fillers. The conceptual framework is shown in Figure 4.

Result and Discussion

Tensile testing results of fiberglass fiber composite material with polyester matrix, Yukalac series 157 BQTN-EX, with the influence of volume fraction.

Table 1 shows the results of the tensile and pull-out tests of glass fiber with variations in the ratio of fiber volume fraction and resin. The parameters measured are tensile strength (MPa), strain, and elastic modulus (GPa). Each variation of fiber and resin volume fraction is represented by five specimens (I- V).

Table 1. Tensile test results

Volume Fraction		Speciment	Stress (Mpa)	Strain	Elastic Modulus (Gpa)
Fiber (%)	Resin (%)				
40	60	I	207.82	30	2.99
		II	190.49	30	2.62
		III	156.18	19	2.9
		IV	195.67	23	2.9
		V	244.83	39	3.2
Average			198.99	28.2	2.93
35	65	I	162.68	47	2.7
		II	170.25	43	2.5
		III	172.04	37	2.4
		IV	151.90	27	2.6
		V	174.46	19	2.67
Average			166.26	34.6	2.59
30	70	I	152.49	19	2.57
		II	168.02	45	2.52
		III	133.73	21	2.49
		IV	150.73	30	2.40
		V	140.70	28	2.37
Average			149.13	28.6	2.47

25	75	I	143.39	33	2.25
		II	133.40	40	2.35
		III	120.29	68	2.04
		IV	111.33	41	1.93
		V	118.85	21	2.01
Average			142.28	40.6	2.12
20	80	I	102.95	32	2.12
		II	105.13	28	2.22
		III	111.75	24	2.24
		IV	119.43	25	2.16
		V	122.6	23	2.18
Average			112.37	26.4	2.18

Using a volume fraction of 40% fiber and 60% resin showed tensile strength results with an average of 198.99 MPa, with the highest value of 244.83 MPa (specimen V) and the lowest 156.18 MPa (specimen III). The strain value averaged 28.2%, with the highest strain of 39% (specimen V) and the lowest of 19% (specimen III). Meanwhile, the elastic modulus averaged 2.93 GPa, with the highest value of 3.2 GPa (specimen V) and the lowest 2.62 GPa (specimen II).

Using a volume fraction of 35% fiber and 65% resin showed tensile strength results with an average of 166.26 MPa, with the highest value of 174.46 MPa (specimen V) and the lowest 151.90 MPa (specimen IV). Strain values averaged 34.6%, with the highest strain of 43% (specimen II) and the lowest of 27% (specimen IV). Then, the elastic modulus has an average of 2.59 GPa, with the highest value of 2.77 GPa (specimen I) and the lowest of 2.5 GPa (specimen II). Using a volume fraction of 30% fiber and 70% resin showed tensile strength results with an average of 149.13 MPa, with the highest value of 168.02 MPa (specimen II) and the lowest of 133.73 MPa (specimen III). The strain has an average of 28.6%, with the highest strain of 45% (specimen II) and the lowest of 21% (specimen III). Meanwhile, the elastic modulus averaged 2.49 GPa, with the highest value of 2.57 GPa (specimen I) and the lowest 2.37 GPa (specimen V).

In testing using a volume fraction of 25% fiber and 75% resin, the tensile strength value has an average of 142.28 MPa, with the highest value of 143.39 MPa (specimen I) and the lowest of 111.33 MPa (specimen IV). The strain values showed an average of 40.6%, with the highest strain of 41% (specimen IV) and the lowest of 23% (specimen III). Then, the elastic modulus has an average of 2.12 GPa, with the highest value of 2.25 GPa (specimen I) and the lowest of 2.01 GPa (specimen V). Using a volume fraction of 20% fiber and 80% resin, the tensile strength had an average of 112.37 MPa, with the highest value of 119.43 MPa (specimen IV) and the lowest of 102.95 MPa (specimen I). Meanwhile, the strain value has an average of 26.4%, with the highest strain of 32% (specimen V) and the lowest of 23% (specimen I). It has an elastic modulus value with an average of 2.18 GPa, with the highest value of 2.24 GPa (specimen II) and the lowest 2.16 GPa (specimen IV).

The highest tensile strength was found at 40% fiber volume fraction and 60% resin, while the lowest tensile strength was found at 20% fiber volume fraction and 80% resin. The highest strain is found in the volume fraction of 25% fiber and 75% resin, while the lowest strain is found in the volume fraction of 20% fiber and 80% resin. The highest elastic modulus was found at 40% fiber volume fraction and 60% resin, while the lowest elastic modulus was found at 25% fiber volume fraction and 75% resin. In general, increasing the fiber volume fraction tends to increase tensile strength and elastic modulus, but has a mixed effect on strain.

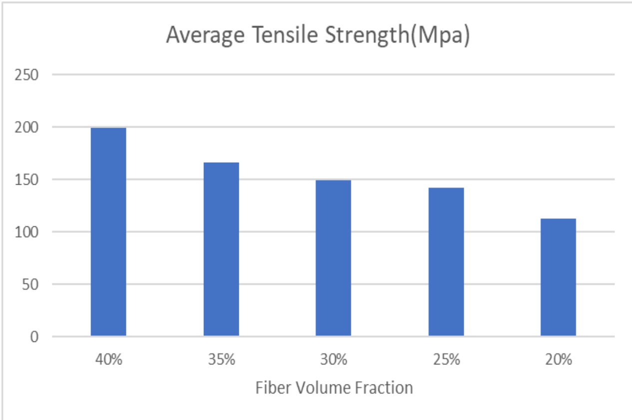

Figure 5. Comparison of the tensile strength of fiberglass composites against volume fraction

The variation of volume fraction based on the figure above has an influence on the tensile strength. The 40% fraction got a tensile strength of 198.99 MPa, the 35% fraction got a tensile strength of 166.266 MPa, the 30% fraction got a tensile strength of 149.134 MPa, the 25% fraction got a tensile strength of 1142.282 MPa, and the 20% fraction got a tensile strength of 110.918 MPa. From the test results, it is known that the highest tensile value is at 40% fraction and the lowest is at 20% fraction, meaning that there is an effect of volume fraction on the composition of composite materials, where the strength increases as the volume of fiber increases. This tensile strength is influenced by alkali treatment, which can remove natural matrices such as hemicellulose, lignin, wax, and oil, which affect the fiber surface.

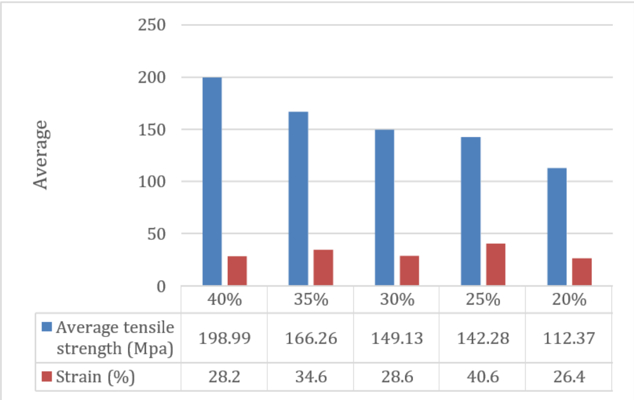

Figure 6. Stress and strain graph of fiberglass fiber composite

Figure 6, the stress and strain of fiberglass fiber composite material with polyester matrix, Yukalac series 157 BQTN-EX, with the influence of volume fraction, can be seen in Figure 5. The fractions used are 40% volume fraction, 35% volume fraction, 30% volume fraction, 25% volume fraction, and 20% volume fraction. Fiber composites with a volume fraction of 40% have a tensile strength of 198.99 MPa as the maximum stress with a maximum strain of 28.2% so that an elastic modulus of 2.9314 GPa is obtained. The fiber composite with a volume fraction of 35% has a tensile strength of 166.266 MPa as the maximum stress with a maximum strain of 34.6% so that an elastic modulus of 2.5916 GPa is obtained. The fiber composite with 30% volume fraction has a tensile strength of 149.134 MPa as the maximum stress with a maximum strain of 28.6% so that an elastic modulus of 2.4754 GPa is obtained. The fiber composite with a volume fraction of 25% has a tensile strength of 142.282 MPa as the maximum stress with a maximum strain of 40.6% so that an elastic modulus of 2.1228 GPa is obtained. The fiber composite with 20% volume fraction has a tensile strength of 110.918 MPa as the maximum stress with a maximum strain of 29.2% so that an elastic modulus of 2.22175 GPa is obtained. Then, the tensile tests for volume fractions of 40%, 50%, and 60% are shown in Figure 7 below.

Figure 7 above shows that the increase in tensile load occurs in composites with fiber volume fractions of 40%, 50% and 60%. The composites with 50% and 60% fiber volume fraction have a tensile load of 5749.3 N, which is greater than the tensile load of the composite with 40% fiber volume fraction, which is 4512.6 N.

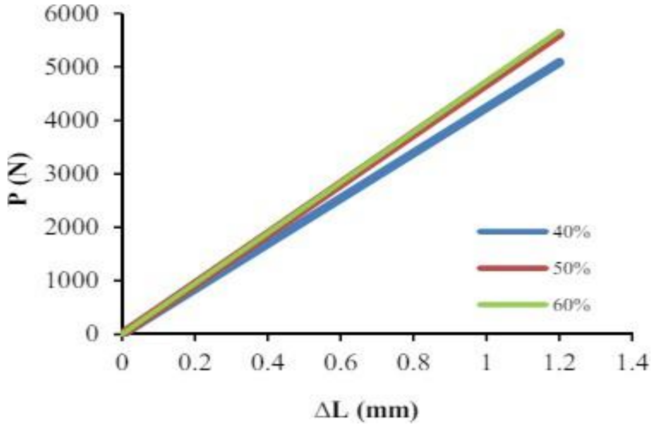

Figure 7. Relationship graph between load P (N) and length increase ΔL (mm) of 40%, 50%, and 60% volume fraction

The tensile load of the composite with 40% fiber volume fraction has the lowest value, with a length increase of 1.2 mm. The relationship between stress and strain due to tensile loading can be seen in the graph in Figure 8 below.

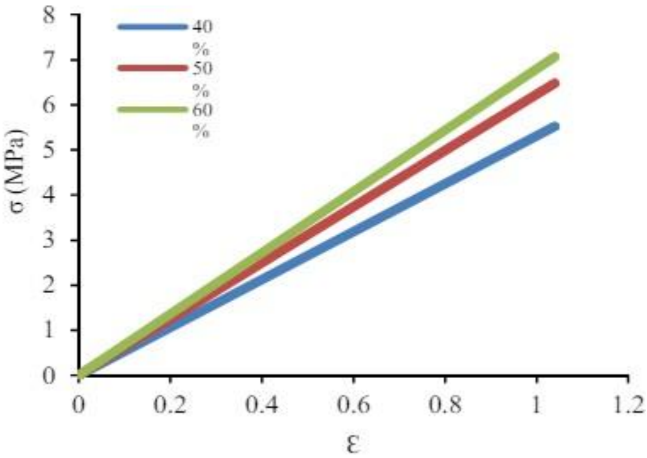

Figure 8. Relationship between stress (σ) and strain (Ɛ)

From Figure 8 above, it can be seen that variations in fiber volume fractions of 40%, 50% and 60% influence the resulting tensile stress. The increase in tensile stress occurs from 40% fiber volume fraction to 50% fiber volume fraction and 60% fiber volume fraction, so that the 60% fiber volume fraction has the highest tensile stress of 7.2 MPa. This shows that increasing the fiber volume fraction can increase the amount of load transferred by the fiber as reinforcement. This is also because the mat works well in binding an increasing number of fibers, accepting the load and passing it on to the fibers as reinforcement. The graph of the relationship between elastic modulus and volume fraction variation of the nylon-polyester composite material is shown in Figure 9.

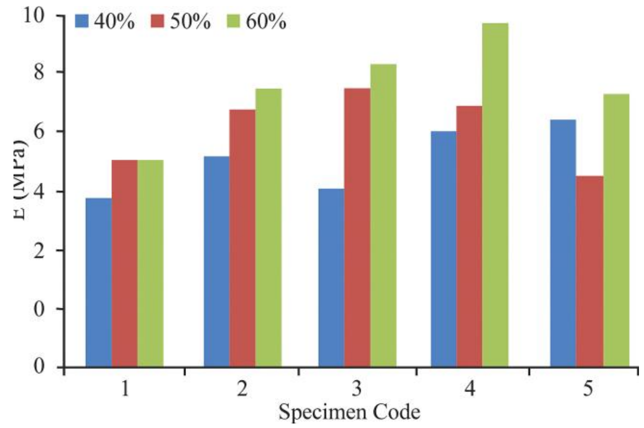

Figure 9. Relationship between modulus of elasticity and fiber volume fraction 40%, 50%, 60%

From Figure 9, it is found that increasing the volume fraction can also increase the stiffness of the material as indicated by its elastic modulus value. This is because the elastic modulus value is directly proportional to the stress value, so that with increasing stress, the elastic modulus also increases. The increase in stress value with increasing fiber volume fraction also increases the stiffness of the matrix because it is reinforced by many fibers. This is also shown by the damage mechanism that occurs, caused by the fiber pull-out mechanism. Fiber pull-out damage indicates that the matrix is strong enough to withstand the initial load so that matrix crack damage does not occur. As the testing load increases, greater load transfer occurs to the fiber as reinforcement. When the load reaches a certain point, the fibers bonded by the matrix break away from their interfacial bonds, so the visible composite damage is fiber pullout.

Conclusion

Based on the results of research and data analysis that has been carried out by varying the value of the volume fraction in the composite, it can be concluded that in the variation of the volume fraction (40%, 35%, 30%, 25%, and 20%) the results obtained are the highest tensile strength value of the 40% volume fraction, namely 198.99 Mpa and the smallest tensile strength value is at a volume fraction of 20%. Based on the test results, it is found that the effect of volume fraction on tensile strength, where the higher the percentage of volume fraction value, the higher the tensile strength value of the composite in the range of 20% to 40%. In each test specimen, debonding or fiber pull-out almost occurs, which occurs due to the selection of the manufacturing method, namely hand lay-up, which is likely to cause voids in the composite specimen.

The strain and modulus of elasticity also vary with the fiber volume fraction. Higher fiber content generally leads to a higher modulus of elasticity but has a mixed effect on strain. The highest strain was observed at a 25% fiber volume fraction, indicating that this composition allows for more elongation before breaking. The highest modulus of elasticity was noted at the 40% fiber volume fraction, suggesting a stiffer material compared to other compositions.

Meanwhile, the fracture patterns of tensile testing composites at 40%, 50% and 60% fiber volume fractions show brittle properties and mechanisms (fiber pull out). The pull-out fiber test revealed that debonding or fiber pull-out is a potential issue, particularly influenced by the manufacturing technique. Proper control during the hand lay-up process is crucial to minimize these defects.

References

[1] S. A. Carli, Widyanto, and H. Ismoyo, “Analysis of tensile and bending strength of woven-type glass fiber composite with epoxy and polyester matrix in symmetrical layers using hand lay-up manufacturing method,” *Universitas Diponegoro*, Semarang, 2012.

[2] R. N. Ichsan and I. M. Arif, “Effect of composite laminate arrangement reinforced by E-glass and carbon fiber on tensile strength with polyester matrix,” *JTM*, vol. 3, no. 3, 2015.

[3] B. Ma’ruf and Farief, “Technology of fiberglass ship construction,” *SBU Marine, PT Biro Klasifikasi Indonesia*, Jakarta, 2016.

[4] B. Ma’ruf, “Analysis of hull laminate strength of fiberglass ships using multiaxial material,” *Jurnal Standardisasi BSN*, vol. 16, no. 1, pp. 77–84, 2014.

[5] B. Ma’ruf, “Study on the standardization of fiberglass ship hull laminate construction,” *Jurnal Standardisasi BSN*, vol. 13, no. 1, pp. 16–25, 2011.

[6] F. Rusmiyatno, “Effect of fiber volume fraction on tensile and bending strength of nylon/epoxy resin random short-fiber composites,” *Universitas Negeri Semarang*, 2007.

[7] I. Marzuki, A. Zubaydi, and B. Ma’ruf, “Study on the application of classification rules in fiberglass fishing vessel hull structure laminates (3 GT),” *Wave: Jurnal Ilmiah Teknologi Maritim*, vol. 11, no. 1, pp. 15–22, 2017.

[8] W. T. Nugroho, "Effect of fiber model on the strength, toughness, and hardness of fiberglass material," *Jurnal Ilmiah Inovasi*, vol. 15, no. 1, 2015.

[9] A. Alam, R. J. Ikhwani, and T. Hidayat, "Strength of fiberglass reinforced plastic (FRP) as a frame material for wooden ships," *Wave: Jurnal Ilmiah Teknologi Maritim*, vol. 15, no. 1, pp. 1–10, 2021.

[10] Tim Fakultas Teknik Universitas Negeri Yogyakarta, *OPKR-60-029A Module: Fabrication of fiberglass/composite components*, 2004.

[11] R. G. Fardhana and E. Sugianto, "Strength analysis of *sandwich* material made of plastic bottles and sengon wood powder for waste collection vessel hull," *Universitas Hang Tuah*, Surabaya, 2023.

[12] R. *Fadilah* and G. Widyaputra, "Analysis of tensile strength and microstructure of composite material on PROSOE KMHE 2019 electric car body," *Jurnal Teknik Mesin*, vol. 9, no. 2, 2020.

[13] E. D. Sulistyowati, "Effect of fiber length and volume fraction on impact and bending strength of polyester–fiber glass and polyester–pandan wangi composites," *Jurnal Keilmuan dan Terapan Teknik Mesin*, vol. 2, no. 1, 2012.

[14] A. Alam, R. J. Ikhwani, and T. Hidayat, "Comparison effect of resin and catalyst on tensile strength of polyester fiberglass composite for shipbuilding materials," *Jurnal Inovasi Sains dan Teknologi Kelautan*, vol. 1, no. 2, 2020.

[15] A. H. Siregar, B. A. Setyawan, and A. Marasabessy, "Fire-resistant fiberglass-based FRP composite as ship body material," *Jurnal Ilmiah Fakultas Teknik UPN "Veteran" Jakarta*, vol. 12, no. 2, 2016.

[16] A. Nurudin, "Potential development of continuous laminated hibiscus tiliaceus fiber-reinforced composites as a fiberglass substitute for ship hull fabrication," *Jurnal Keilmuan dan Aplikasi Teknik*, vol. 12, no. 2, 2011.

[17] P. P. Tambunan, H. Yudo, and P. Manik, "Technical analysis of laminated board of petung bamboo fiber and fiberglass woven roving for ship hull skin material," *Jurnal Teknik Perkapalan UNDIP*, vol. 10, no. 2, 2022.

[18] H. Yudo and S. Jatmiko, "Technical analysis of mechanical strength of bagasse fiber-reinforced composite material in terms of tensile and impact strength," *Jurnal Ilmu Pengetahuan dan Teknologi Kelautan*, vol. 5, no. 2, 2008.