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Study of The Potential of Palm Oil Empty Core Fiber As Composite Materials for Ship Hull

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KEYWORDS
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Fraction Volume
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ABSTRACT–Palm oil is the largest commodity in Indonesia. Pprocessing of oil palm, leaving 20% to 23% empty palm fruit bunches (EFB). Oil palm empty fruit bunches (EFB) is a collection of fiber left behind after separating the fruit from fresh fruit bunches that havebeen sterilized. Some researchers use natural fibers as an alternative for making composites.This study aims 1. To determine the tensile strength of the alternative material of palm emptyfruit bunch fiber. 2. To determine the buckling or bending strength of the alternative fiber material for empty palm oil bunches. The method used is the tensile and bending test methodin the process of mixing the fiber material of empty palm oil bunches in the manufacture of composites. The test results obtained were compared with the BKI composite standard. The volume fraction used in this study was 30% polyester resin and 70% EFB fiber, 40% polyester resin and 60% EFB fiber and 50% polyester resin and 50% EFB fiber with NaOHalkaline treatment for 2 hours. The average tensile stress values obtained for each fraction were 27.372 MPa, 24.168 MPa and 25.875 MPa respectively. The values for the bending stress of each fraction are 144.836 Mpa, 149.059 Mpa and 164.682 Mpa respectively.

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INTRODUCTION

Oil palm (Elaeisguineensis) is one of the commodities with the highest productivity in Indonesia. Based on data fromthe ministry of agricultural plantations, in 2021 it is recorded that Indonesia's oil palm area will reach 15,008,000 ha. Itis estimated that Indonesia's total palm oil production will reach 49,710,000 tons. From the results of this productivity,palm coir is one of the wastes in the palm oil processing industry. The main product of the oil palm tree that is utilized is the fruit bunches which produce oil from the pulp and kamel (palm kernel). After processing the oil palm, it will leave20% to 23% empty palm fruit bunches (EFB).

The development of the palm oil industry is currently increasing rapidly, this is because the demand for palm oil is increasing every year. With the increasing production of palm oil which continues to increase, resulting in more and more waste of empty palm oil bunches. Empty palm oil fruit bunches (EFB) is solid waste produced by factories or palmoil processing industries. The community has traditionally used empty oil palm fruit bunches as compost which will bereused as fertilizer in oil palm plantations, but this has not reduced the waste from the EFB.

Initially, the developing composite technology was made from synthetic fiber reinforcement. Synthetic fibers are fibers made by chemical synthesis with extrusion fiber material through the spinneret, producing a fiber. With the development of science and technology in the industry, it continues to carry out research in the field of materials, wherenatural fibers are developed. This is because natural fibers have advantages, namely having good physical properties, abundant content in nature, environmentally friendly, and lower production costs. Composite is a material formed froma combination of two or more materials, where the mechanical properties of the forming materials are different. Due tothe different characteristics of the materials, new materials will be produced, namely composites which have different mechanical properties and characteristics from the constituent materials [1].

One of the natural fibers that is used as the object of research is palm fiber belt which is made into composites. Oil palm empty fruit bunches are a collection of fibers left behind after separating the fruit from fresh fruit bunches that have been sterilized. Oil palm empty fruit bunches are a natural fiber that can be decomposed, non-toxic and widely used. Oil palm empty fruit bunches are widely used as raw materials in various applications including power generation, composite formulation, and their use in polymer composites can solve environmental problems, especially those relatedto the disposal of palm oil waste. The matrix properties of natural fiber reinforced polymer composites need to be considered. This is related to the compatibility between the fiber and the matrix and the hydrophilic nature of the fiber. Composites usually contain two mixed materials, namely fiber and matrix. In general composites are considered multiphase materials which exhibit a significant proportion of both phases of arrangement so that a better combination of properties can be achieved [2].

Palm fiber has a hard and strong nature. The pores on the surface of the palm fiber have an average diameter of 0.07 m. This pore surface morphology is very useful for increasing the mechanical bond with the resin matrix when used in the manufacture of composites. In EFB microfibrils there are cellulose, lignin, and hemicellulose as the main components. Cellulose serves to form pores in the composite. Cellulose is a water-insoluble, fiber-like compound foundin the protective cell walls of plants [3].

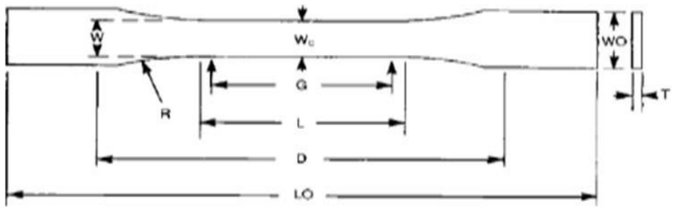
Several previous scientific studies related to the fiber of empty palm oil bunches have been carried out. [4] researchers used resin, with a volume fraction of 80%, 85% and 90% and empty palm fruit fiber with a volume fractionof 15%, 10% and 5% and a catalyst volume fraction of 5%. The results that showed the highest tensile strength were thefraction with a volume of 90% resin, 5% empty palm fruit fiber and 5% catalyst with a value of 97.42 kgf/mm2. From research conducted by [5] researchers used epoxy resin, empty palm fruit bunch fiber with a volume fraction of 3%, 5%and 8%. The highest tensile strength results were shown in the volume fraction of 3% EFB fiber with a value of 30 MPa.In the current study using polyester resin, EFB fiber with a volume fraction of 70%, 60% and 50%. Oil palm empty fruitbunches fiber is applied as a composite material in ship hulls. Composite production is done conventionally using the hand lay-up method. After the results are obtained from the tensile and bending testing process, then the calculation process is carried out. The calculations performed calculate the values of tensile strength and strain as well as bending strength.

The use of natural fibers has become an option in several industrial applications. Based on this, the researchers used empty palm oil bunches as an alternative material for composite materials on fiber glass boat hulls. This research was carried out by testing the tensile and bending strengths to determine the feasibility of fiber as an alternative composite in ship hulls. Where it is expected that this fiber composite can be the material of choice in the manufacture of various products as a substitute for metal and fiberglass which are considered more environmentally friendly and have good quality.

METHODS

In this paper a laboratory experimental method is applied using a destructive test (DT). The types of damage tests performed are tensile tests and bending tests. The applied strength test refers to ASTM D-638-03 standard for Tensile test and ASTM D-790 bending test. Before entering the testing phase, the steps for making a composite specimen of palm fiber with the design and size as shown in Figure 1. The stages for making the specimen are described as follows:

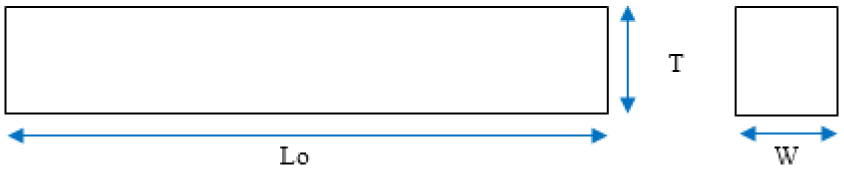
1. The preparation of empty palm fruit bunches includes cleaning the empty palm fruit bunches with water first. Then the fiber from the empty palm oil bunches is separated by the mechanical pulling method. After that the fiber that has been obtained is soaked in an alkaline solution of NaOH for 2 hours. The next step is to dry the empty palm fruit bunches in the sun until the water content contained in the empty palm fruit bunches has dried.
2. The process of weighing polyester resin and coconut empty fruit bunches according to the volume fraction was30% and 70%, 40% and 60%, and 50% and 50% respectively with NaOH alkaline treatment for 2 hours.
3. Resin and catalyst are poured into a measuring cup according to the volume fraction that has been calculated. Then the mixture of resin and catalyst is stirred for 5-10 minutes until evenly distributed.
4. The mixture of resin and catalyst is then poured halfway into the mold evenly by the Hand Lay-Up method
5. The fibers are inserted into the mold according to a predetermined volume fraction variation, then the fibersare neatly arranged using a random method.
6. After the fibers are arranged evenly, the resin is poured until it runs out and then flattened using the Hand Lay-Up method.
7. The mold is covered with glass and given pressure with a brick ballast to avoid things that can damage theprinted specimen.
8. The drying process lasted for 1 day and after drying the composite was then released from the mold using acutter. Then the composite is aerated until it is really hard.



where ;

Lo = 165 mm
D = 115mm
Wow = 19mm
W =13mm
T = 5mm
R = 76mm
G =50mm

ASTM D-638-03 Tensile Test Specimen Size



where ;

Lo = 250 mm
W =25mm
T = 5mm

Figure 1. ASTM D-790 Bending Test Specimens

Further testing is carried out using the UTM test equipment. From the test results, the load and elongation values that occur in the specimen will be obtained. The data obtained from the test is processedto obtain information on the strength value of the proposed material innovation.

Tensile Test

The tensile test is loading slowly and the movement is stiff. Experimental tools for tensile testing must have a strong grip and high stiffness. Specimens with a standard size are given an axial tensile force that increases continuously at both ends of the specimen and is pulled until it breaks [8]. The engineering stress-strain curve is obtained from measurements of the elongation of the test piece. The stress used in the curve is the average longitudinal stress from thetensile test which is obtained by dividing the load by the initial cross-sectional area of the test object. Tensile testing is carried out by machine according to ASTM D 638 tensile test standards or by universal testing standards. In the proportional region, namely the area where the stress-strain that occurs is still proportional, the deflection that occurs isstill elastic and Hooke's law still applies. The magnitude of the composite elastic modulus value which is also the ratio between stress and strain in the proportional area can be calculated by equation [9].

$$E = \frac{\sigma}{\epsilon} \tag{1}$$

where ;

E = tensile modulus of elasticity (MPa)
= tensile strength (MPa)
ε = strain (mm/mm)

The force or load used to pull a specimen apart is called the maximum force. If this maximum load is divided by the original cross section, the tensile strength of the material per unit area will be obtained. The equations for the values of Tensile stress, strain and elongation are applied as follows:

tensile stress

$$\sigma = \frac{F}{Ao} \quad (2)$$

strain

$$\varepsilon = \frac{\Delta l}{Lo} \times 100\% \quad (3)$$

elongation

$$e_f = L_f - L_o / L_o \quad (4)$$

where ;

F = Tensile Load (N)
A_0 = Initial cross-sectional area of the specimen
ΔL = increase in length (mm)
L_0 = initial length (mm)
Ef = elongation (mm)
Lf = Fault Length (mm)

The relationship between the stress and strain exhibited by a particular material is known as the stress-strain curve of that material. For each material and is found by recording the amount of deformation (strain) at different intervals of various loadings (stresses). The stress and strain curves of the composite materials are shown in Figure 2.

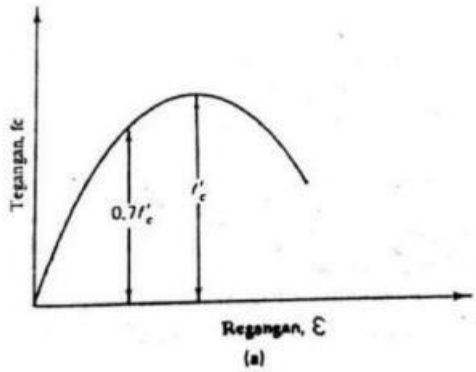


Figure 2. Stress-Strain curve of a brittle material [10].

From Figure 4 the stress and strain curves illustrate many material properties. In general, the curve that represents the relationship between stress and strain in any form of deformation can be thought of as a stress-strain curve. Stresses canbe normal, shear, or mixed, they can also be uniaxial, biaxial, or multiaxial, and even change over time. The form of deformation can be compression, stretching, torsion, rotation, and so on.

Bending Test

A bending test is a form of testing to determine the quality of a material visually or in other words a bending test is a test that can determine the quality of a material because it can provide information about its bending strength [11]. In addition, the bending test can also provide information about the elastic modulus of the material. The bending test is also used to measure the strength of the material due to loading.There are 2 types of bending tests, namely 3 bending points and 4 bending points. As for this writing, the bending test standard for the polymer matrix composite material reinforced by the fiber of empty palm oil bunches used is ASTM D 790-03 using the type of support for the three-pointbending test. This test is mainly used for hard and elastic materials. In order to minimize the effect of friction during thetest, the anvil can be installed so that it rotates about its longitudinal axis. Load mounts can be used with top anvils andanvil supports to ensure that they are parallel to the specimen. Before carrying out this test, a specimen measurement isfirst carried out to determine the length of the specimen using the formula below [12]:

$$\sigma_f = \frac{3PL}{2bd^2}. \quad (5)$$

where ;

σf = bending stress (kgf/mm^2)

P = load or force that occurs (kgf)L = point distance (mm)
b = width of test object (mm)
d = Thickness of the test object (mm)

Fiber Composition

In the manufacture of composites, the amount of fiber composition is of particular concern for the strength of the composite. To obtain high-strength composites, the distribution of fibers with the matrix must be uniform in the mixing process in order to reduce voids. To calculate the volume fraction, the parameters that must be known are the specific gravity of the resin, the specific gravity of the fiber, the weight of the composite and the weight of the fiber [13]. In the manufacture of composites can be done using the fraction equation. There are two fractions used in the manufacture of composites, namely the fiber volume fraction and the composite weight fraction. In determining the volume of the composite, the following equation can be used:

$$Vc = P.\ l.\ t \tag{6}$$

where ;
Vc = mold volume (cm^3)
P = composite length (cm)
L = composite width (cm)
T = composite thickness (cm)

After obtaining the calculated value of the composite volume, the next step is to look for the composite volume, which can be calculated using the following equation:

$$Vc = (\%\ Fiber\ x\ Vf) + (\%matrix\ x\ Vr) \tag{7}$$

where ;
Vc =composite volume (cm^3)
Vf = fiber volume (cm^3)
Vr = volume of resin (cm^3)

RESULTS AND DISCUSSION

Tests on innovative material specimens have been successfully carried out using destructive tests. The display of the specimen being tested can be seen in Figure 3 for the Tensile test specimen and Figure 4 for the bending test specimen.The test conditions are shown in Figure 5. Next, the data processing products will be discussed from the test results as follows:

Figure 3. Specimens for Tensile Test

Figure 4. Bending Test Specimens

(a)

(b)

Figure 5. (a) Tensile Test, (b) Bending Test

In this study, the composition of the composite material was varied, namely the volume of polyester material and fiber material volume. The variation of the composition used is 30% resin + 70% fiber is coded R30, 40% resin + 60% fiberis coded R50.

Tensile strength

After carrying out a tensile test with the ASTM D-638-03 standard, the test data can be collected in table 2.

Table 2. Tensile Test Data Results

volume fractions									
Polyester Resin (%)	EFB Fiber (%)	Simulation	Tensile Stress (Mpa)	Stress Average	Strain s (%)	Average Strains	Elastic Modulus (MPa)	oads(N)	ongation (mm)
		1	34,506	25,875	0.012	0.009	2803,913	3191,787	2,031
30	70	2	22,274		0.019		1191,033	2060,390	3,086
		3	20,844		0.013		1645,331	1928,038	2,090
		1	19,525	24,168	0.012	0.013	1634,713	1806,101	1,971
40	60	2	23,996		0.017		1400,535	2219,599	2,827
		3	28,982		0.011		2583,007	2680,861	1,851
		1	24,348	27,372	0.006	0.015	4118,800	2252,269	0.975
50	50	2	25,481		0.011		2373,083	2357,007	1,772
		3	32,286		0.012		2758,797	2986,481	1,931

Based on the data obtained in Table 2, it can be seen the results of tests of tensile strength, strain, modulus of elasticity, force, and elongation with a volume fraction of polyester resin 30%, 40% and 50% and a volume fraction ofempty oil palm fruit bunches 70%, 60% and 50% with NaOH alkaline treatment for 2 hours.

Table 3 shows that the average tensile strength of the tensile test of empty palm fiber fruit bunches and polyester resin is 27.372 MPa and the minimum value is 24.168. While the highest average strain value is 0.088 and the minimum strainis 0.021. Based on these data, a graph of the relationship between tensile strength and average strain for each volume fraction can be produced.

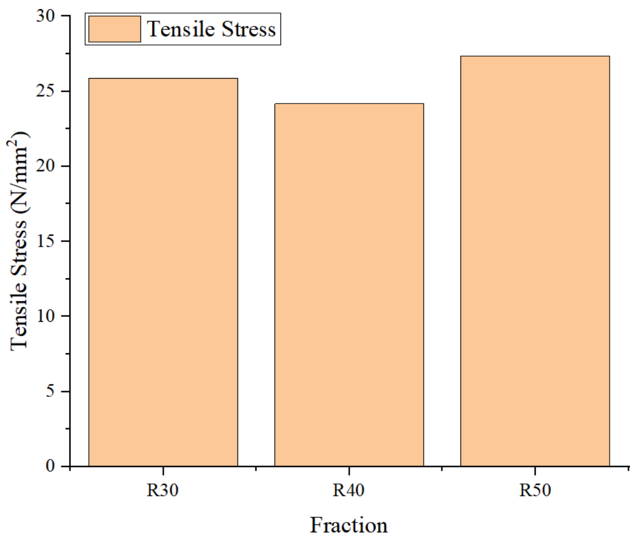


Figure 6. Distribution of Average Tensile Stress for Each Volume Fraction

From Figure 6 it can be seen that the composite material with the highest tensile strength is a fiber composite material with a variation of 50% resin and 50% EFB fiber with a value of 27,372 MPa. This shows that the composite with a variation of 30% resin and 70% EFB fiber has stiffness compared to both composites so that it will increase the ability of the composite to withstand loads. This strength is affected by the increase in fiber percentage, so the resin and fiber bonds become better. For the tensile strength of the EFB fiber composite with a variation of 40% resin and 60% EFB fiber, it has a tensile strength of 24.168 MPa, which has a relatively low value.

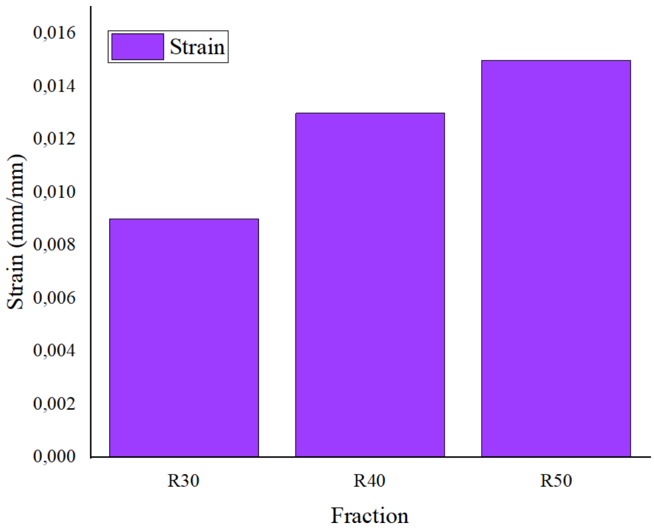


Figure 7. Average Strain Distribution for Each Volume Fraction

For composite materials with the highest strain values, namely fiber composite materials with a variation of 30% polyester resin and 70% EFB fiber with a value of 0.015. This is because with an increase in the percentage of fiber-eating resin contained in the specimen, it decreases, causing the strain value to be higher compared to the volumefraction of other specimens. The volume fraction of 40% polyester resin and 60% EFB fiber has a strain value of 0.013,this is because the reduced percentage of resin causes the fibers to bind to the resin by making the resin well, so that when the specimen is stretched it becomes smaller. For volume fraction specimens 50% resin and 50% EFB fiber had astrain value of 0.090, this is because the fiber binds the resin well, so that when the specimen is stretched it becomes very small. From Figure 5 above, the fracture of the tensile test specimen shows that the failure mode of the compositeis that the matrix cannot withstand large stresses so that the specimen breaks.

Bending Strength

While for the fracture of the bending test specimen it shows that the matrix is able to withstand the shear force received but cannot be continued so that the specimen breaks. From the data obtained, it can be said that the tested composite has brittle properties because the specimen is given a load and experiences elastic deformation and then the specimen breaks.the results of the tensile test will be explained as follows.

Table 4. Bending Test Data Results

Volume Fractions								
Polyester Resin (%)	EFB iber (%)	Simulations	oads(N)	*bending* Stress(N /mm2)	Bending Stress Average (N/mm2)	eflection (mm)	Deflection Average(mm)	Elasticity (N/mm2)
		1	820,350	157,507	144,836	6,834	6,562	10900
30	70	2	717,010	137,665		6,277		11281
		3	725,710	139,336		6,576		11119
		1	602,880	115,752	149,059	3,905	5.014	13094
40	60	2	827,380	158,858		5,380		13710
		3	898,780	172,566		5,758		14478
		1	788,430	151,378	164,862	6,216	5,619	10232
50	50	2	781,360	150,021		5,261		11551
		3	1006,200	193,185		5,379		14657

Based on the data obtained in table 2 above, it can be seen the results of tests on bending strength, strain, modulus of elasticity, force, and elongation with a volume fraction of polyester resin 30%, 40% and 50% and a volume fraction of empty oil palm fruit bunches 70%, 60% and 50% with NaOH alkaline treatment for 2 hours. To make it easier to knowthe bending strength and pressure values of each fraction or sample, the average is taken for each volume fraction.

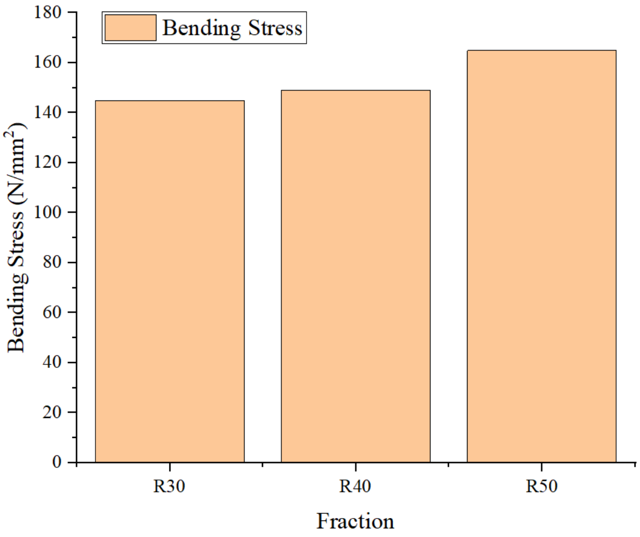


Figure 8. Average Bending Stress Distribution

Based on Figure 8 the bending stress of the EFB fiber specimens, it was found that the composite fiber of emptybunches with a volume fraction of 50% polyester resin and 50% of EFB fiber with alkaline NaOH treatment for 2 hourshad a bending strength value of 164.862 Mpa, while for the composite fiber of empty palm fruit bunches with a volumefraction of 30% polyester resin and 70% EFB fiber has a strength of 144.836 MPa and for composites with a volume fraction of 40% polyester resin and 60% EFB fiber has a strength of 149.059 MPa. By looking at the graphs and data obtained, composites with 50% polyester resin and 50% EFB fiber fractions with NaOH alkaline treatment for 2 hours had the highest bending strength values. From the results of the data obtained, it can be said that the composite tested has brittle properties because the specimen experienced cracks at the bottom during the bending test. This can be causedby the specimen not being able to withstand tensile stress due to large bending loads.

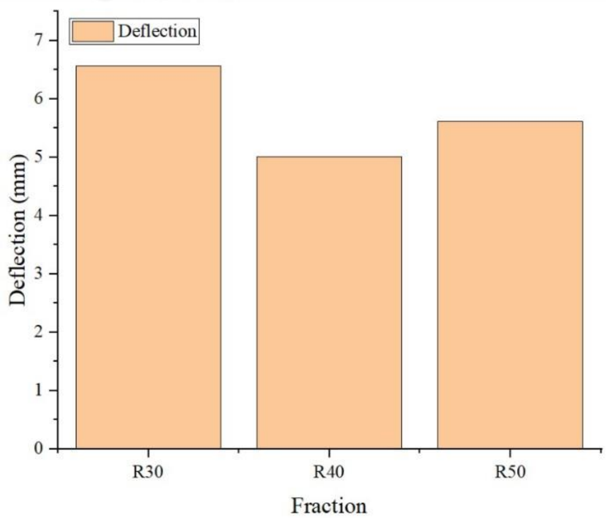


Figure 9. Average deflection bar chart

Based on pictures9 The average deflection of EFB fiber specimen bending test specimens showed that the composite with a volume fraction of 30% polyester resin and 70% EFB fiber treated with alkaline NaOH for 2 hours had a deflection value of 6.562 mm. For the volume fraction composite 40% polyester resin and 60% EFB fiber treatedwith alkaline NaOH for 2 hours had a deflection value of 5.014 mm. For composites with a volume fraction of 50% polyester resin and 50% EFB fiber with NaOH alkaline treatment for 2 hours had a deflection value of 5.619 mm. Fromthese data the composite with a fraction of 30% polyester resin and 70% EFB fiber with NaOH alkaline treatment for 2hours had the highest deflection value.

CONCLUSION

Based on the tensile test and bending test that have been carried out successfully, the research data is obtained for each volume fraction of the test specimen. The highest value for the average tensile test results for the volume fraction of 30% polyester resin and 70% EFB fiber, the volume fraction of 40% polyester resin and 60% EFB fiber and the volume fraction of 50% polyester resin and 50% EFB fiber were 25.875 MPa respectively , 24.168 Mpa and 27.372 Mpa. The optimum value was obtained for volume fraction specimens of 50% polyester resin and 50% EFB fiber. The highest value for the average bending test results for the volume fraction of 30% polyester resin and 70% EFB fiber, thevolume fraction of 40% polyester resin and 60% EFB fiber and the volume fraction of 50% polyester resin and 50% EFB fiber respectively were 144.836 Mpa, 149.059 Mpa and 164.682 Mpa. The optimum value was obtained for volumefraction specimens of 50% polyester resin and 50% EFB fiber. Based on the results of the tensile test and bending test carried out, optimum values for tensile strength and bending strength were obtained and then compared with BKI standards. The test value data that has been carried out does not meet the hull standards according to BKI standards where the standard values for the tensile test are 151.52 MPa and for bending strength are 170.680 MPa. The results ofthis test can be used as equipment for ships such as furniture, dashboards, fish cooler boxes and so on.

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