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Analysis of Tensile Strength of Citronella (*Cymbopogon Nardus*) Fiber Reinforced Composite Materials

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ABSTRACT

The use of synthetic fibers in composite materials has a negative impact on the environment. One way to reduce this impact is to replace synthetic fibers with natural fibers. A natural fiber that has the potential as a mixed material in the manufacture of composite materials is citronella (Cymbopogon nardus) fiber. This study aims to determine the effect of volume fractions 40%, 50%, 60%, and 70% of citronella fiber with polyester resin matrix BQTN 157 on tensile strength. The process of making composites used the hand lay-up method. The specimen was formed according to the ASTM D3039 standard and the tensile strength of the specimen was tested by using a Universal Testing Machine (UTM). From the results of the study, the maximum tensile strength was found in the fiber volume fraction 70% of 77.35 MPa, the strain is 6.57%, and the modulus of elasticity is 1.177 GPa. This study indicates that fiber volume fraction affects the tensile strength of composite materials. Hence, the manufacture of composite materials which have good strength is influenced by many things such as raw materials, matrices, mixture composition, and methods.

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1. INTRODUCTION

The development of materials technology, including composites, is still in demand by the general population. It is due to the advantages of composite materials which are easily constructed, lightweight, low-priced , and environmentally friendly [1]. The most common reinforcement fiber used by the community in composites processing is carbon, glass, and ceramics. However, the use of synthetic fibers will certainly cause damage to the environment because it is difficult to decompose naturally, therefore natural fibers appear as a substitute for synthetic fibers [2]. The mechanical properties of composite materials are influenced by several factors, including the manufacturing process and the constituent materials [3]. According to [4] one that affects the material strength is the matrix. The weakness of synthetic fiber composites is relatively overpriced and it has a tendency to damage the environment [5]. Scientists have found a replacement fiber that is environmentally friendly, non-toxic, relatively inexpensive , and its strong ability can match synthetic fibers [6].

One of the replacements for synthetic fiber is a natural fiber which has the potential to be developed into composite materials. Applications of natural fiber-reinforced composite materials have been widely used such as in connecting rods in vehicles, aerospace, shipping , and sports equipment [7]. The advantages of using natural fibers are accessible raw materials, non-toxic content, ease to recycle , and low environmental impact [8]. The tensile strength of various fibers can be seen in Table 1.

Table 1 : Tensile strength of some fibers [9]

Material	Tensile strength (MPa)	Young's modulus (GPa)	Elongation (%)
e-glass	1200-1800	72	~2.5
Carbon	~4000	235	~2
Hemp	350-800	30-60	1.6-4.0
Kenaf	400-700	25-50	1.7-2.1
Jute	300-700	20-50	1.2-3.0

One type of natural fiber that has the potential to be used as a composite raw material is citronella *(Cymbopogon nardus)*, which is one of the plants that are easy to cultivate. It has various benefits and has been used for aromatherapy, food preservatives, and perfumes [10]. The citronella plant is processed to extract the oil, and the waste from the distillation is usually used as fuel during the refining process. It is also used as animal feed and raw material for organic fertilizers. Citronella plants contain essential oils produced from distillation, in which distillation waste has the potential to be used as animal feed because it contains about 7% protein and high fiber [11]. The composition of chemical compounds in citronella stems can be seen in Table 2.

Table 2 : Chemical compounds in the stems of citronella *(cymbopogon nardus)* [12]

Chemical Compound	Amount (%)
cellulose	39.5
hemicellulose	22.6
lignin	28.5

The processing of citronella waste cannot be optimized because this waste is directly disposed of or burned. The use of this waste is certainly beneficial from an economic point of view in the manufacture of composite materials. Therefore, the high fiber content in citronella plants can be used as a mixture to form composite materials [13]. This study aims to utilize citronella waste for the manufacture of composite materials.

2. METHODS

This research was an experimental study in which the test results were obtained directly from the specimen. Tools and materials used in the manufacture of composites include,

Materials:

- Citronella Fiber

Figure 1 : Citronella Fiber.

- Polyester Resin Yukalac 157 BQTN and Catalyst

Tools:

- Universal Testing Machine (UTM)

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Figure 2 : Universal Testing Machine

- Digital scales
- Measuring cup
- Sample Mold
- Ruler

The manufacture of composite materials used the hand lay-up method. This study focused on the effect of fiber volume fractions 40%, 50%, 60%, and 70% with resin matrix BQTN 157 Yukalac on the tensile strength of composite materials. This test used the ASTM D3039 standard based on Table 2.

Table 3 : Tensile Specimen Geometry Reqiurements [14]

Parameter	Requirement
Compound Requirements:	
Shape	Constant rectangular cross-section
Minimum length	Gripping + 2 time width + gage length
Specimen Width	As needed
Specimen width tolerance	± 1 % of width
Specimen thickness	As needed
Specimen thickness tolerance	± 4 % of thickness
Specimen flatness	Flat with light finger pressure
Tab requirement	
Tab material	As needed
Fiber orientation	As needed
Tab thickness	As needed
Tab thickness variation between	± 1 % tab thickness
Tab bevel angle	5 to 90°, inclusive

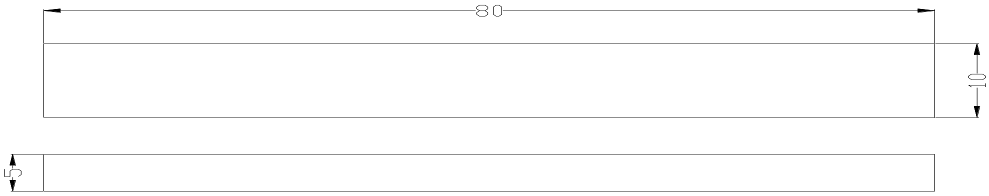

Figure 3 : Dimensions & Geometry of ASTM D3039 specimen without tabs

The dimensions of the specimen were 80mm x 10mm x 5mm without tabs with a test area length of 60mm and a grips area of 10mm on each side of the specimen. Tensile testing aims to determine the mechanical properties of a material such as stiffness, ductility , and strength[15]. This test was carried out by applying a tensile load to the specimen until it was broken, and the resulting data was in the form of stress-strain curve, elongation, and modulus of elasticity. Stress is a force per unit area, and it was obtained by equation 1.

$$\sigma = \frac{F}{A} \quad (1)$$

Strain is the increase in the length of the object per initial length. Strain was obtained by equation 2.

$$\varepsilon = \frac{\Delta l}{lo} \quad (2)$$

According to [16] Volume fraction is defined as a combination of fiber volume and matrix volume used to determine the composite volume, through equation 3.

$$v_c = v_f + v_m = \frac{m_f}{\rho_f} + \frac{m_m}{\rho_m} \quad (3)$$

As a control material, the fiber volume fraction can be obtained by equations 4 and 5.

$$V_f = \frac{v_f}{v_c} \times 100\% \quad (4)$$

$$W_f = \frac{m_f}{v_c} \times 100\% \quad (5)$$

2.1 Composite Manufacturing Process

The raw material was obtained from the citronella distillation waste in South Limau Manis, Padang. Citronella stem waste was soaked for 3-4 days. This process was intended to let the substances attached to the fibers soften so it facilitated the separation of the fibers in the stems. The process of separating the fibers in the citronella stems was done by shaving the citronella stems repeatedly until clean fibers were obtained and then dried without sunlight. The dried fibers were soaked in an alkaline solution (5% NaOH) for 30 minutes, then the fibers were cleaned with running water and dried without sunlight. The matrix used was polyester resin yukalac BQTN 157. Composites were made by hand lay-up method. The ratio of resin and hardener was 10:1 and the fiber volume fraction (Vf) was 40%, 50%, 60%, 70%. The tensile test sample was printed using glass and it was pressed. Then the sample was cut to form a specimen according to the ASTM D-3039 standard. The specimen pieces were smoothed using sandpaper. The tensile testing used UTM (Universal Testing Machine) with a capacity of 50 kN. The results are shown in the form of the relationship between tensile properties and fiber volume fraction (Vf).

3. RESULTS AND DISCUSSION

Specimen testing was carried out by using universal Testing Machine (UTM). The average tensile test results can be seen in Table 4.

Table 4 : The results of average tensile test of the composite

Volume Fraction		**Tensile Strength (MPa)**	**Strain (%)**	**Modulus of Elasticity (GPa)**
Fiber	**Resin**			
40%	60%	46.5	8.00	0.581
50%	50%	51.59	8.3	0.644
60%	40%	55.71	7.33	0.775
70%	30%	77.35	6.57	1.177

It can be seen in table 3 the results of the average tensile test on fiber volume fractions of 40%, 50%, 60% , and 70% of the resin yukalac BQTN 157. So that the graph of the relationship between stress and volume fraction is obtained in Figure 4.

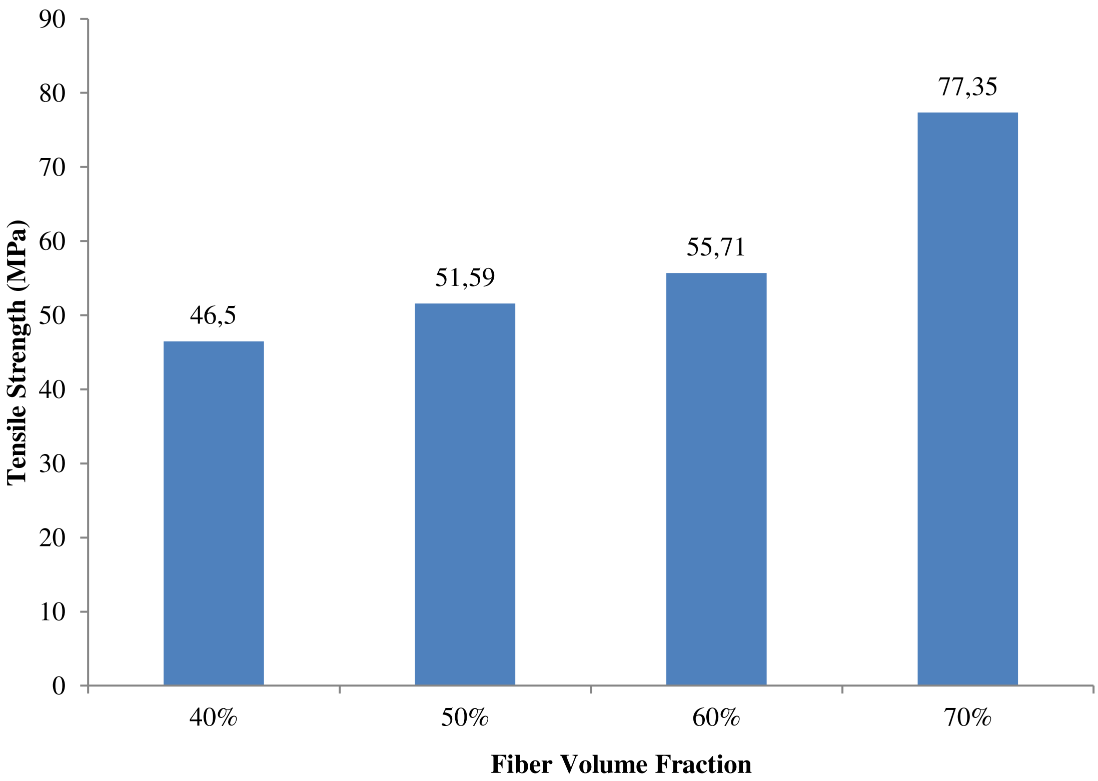

Figure 4 : Graph of the relationship between tensile strength and fiber volume fraction

The graph shows the tensile strength in the fiber volume fraction 40% with a value of 46.5 MPa. In the volume fraction of 50% it has a tensile strength of 51.59 MPa. The fiber volume fraction 60% has a tensile strength of 55.71 MPa and the tensile strength value in the volume fraction 70% is 77.35 MPa. The above research proves that there is an effect of volume fraction on the tensile strength of composite materials. The results of this study are in line with the opinion of [17]. According to him, the tensile strength of the composite material increases with the increase in the volume fraction of the fiber.

4. CONCLUSION

Based on the above research, it can be concluded that the variation of the fiber volume fraction has an effect on the tensile strength of the composite material, where the volume fraction of 70% fiber produces a maximum tensile strength of 77.35 MPa while the volume fraction of 40% fiber produces a minimum tensile strength of 46.5 MPa. The test results indicate that the tensile strength of the composite increases with increase in fiber volume. The manufacture of composite materials which have good strength is influenced by many things such as raw materials, matrices, mixture composition, and methods.

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NOMENCLATURE

σ	Tensile Stress (MPa)
F	Force (N)
A	Area (mm^2)
ε	Strain (%)
Δl	Length Increase (mm)
lo	Initial Length (mm)
v_c	Composite volume (cm^3)
v_f	Fiber volume (cm^3)
v_m	Matrix volume (cm^3)
m_f	Fiber mass (gr)
ρ_f	Fiber density (gr/cm^3)
m_m	Matrix mass (gr)
ρ_m	Matrix density (gr/cm^3)
V_f	Fiber volume fraction (%)
W_f	Fiber weight fraction (%)

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