INTEK Jurnal Penelitian
Vol. 10, No. 2, pp. 114-120, October 2023

Comparison of The Pull Strength of Sisal Lamina Matrix Polymer Fiber Composite Materials (Agave Sisalana)

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Abstract— **Composites are one of the material engineering technologies developed today because composites can combine several material properties that differ in characteristics into new properties by the planned design. The purpose of this study was to determine the mechanical properties of the influence of the combined arrangement of lamina angle variations and the composition of fiber and matrix mixtures. This study uses polyester resin, catalyst, and sisal fiber as materials in the manufacture of composite materials. In specimen manufacturing refers to ASTM D 638-02 type 3 test standard for tensile tests. The tensile test results of sisal fiber lamina composite materials assuming a composition ratio of 5% fiber and 95% resin produce maximum tensile stress of m = 16.9854 N/mm2 and a maximum strain of ε = 4.5232% while assuming a composition ratio of 15% fiber 85% resin produces maximum tensile stress of σ_m = 40.1422 N/mm2 and maximum strain of ε = 8.9744 %, Based on the test results, the addition of fiber mixture composition increases the tensile strength and toughness of the material. The composition of 5% fiber 95% and 15% fiber 85% resin (15S-85R)produces a maximum tensile stress of $\sigma_{m\,=}$ 45.1823 N/mm2 and a maximum strain of ε = 9.6849 % with a maximum load Fm = 10902.4996 N. The more fiber contained in the sisal fiber lamina composite material, the higher the tensile stress produced, this shows the tension is directly proportional to the number of fibers contained in the composite.**

Keywords— Tensile Test, Mechanical Properties, Laminated Composite, Sisal Fibers, Polymers.

I. Introduction

Currently, the development of material technology is experiencing very rapid development. Researchers are racing to discover and create new types of materials, which have better mechanical properties. One type of material currently being developed is composite.

Composite is one of the material engineering technologies developed today because composites can combine several material properties that differ in characteristics into new properties according to the planned design [1]. In general, a composite is a combination of two parts, namely the matrix and reinforcement [2]. Based on the source, reinforcement (fiber), can be categorized into natural fiber and synthetic fiber. However, the development of natural fibers as reinforcement is less desirable, compared to synthetic fibers [3].

One type of natural fiber that can be used is sisal fiber *(Agave Sisalana).* Sisal plants are plants which stems and leaves are fused, have strong fibers, can live on land with a thin processing layer (many surface stones), or are classified as critical land. It is stronger than other fibers and is resistant to high salt content [4]. Sisal fibers are effective polymer reinforcement [5]. The physical properties and mechanical properties of sisal fibers affect angular orientation [6]. In addition, the increase in variation in fiber percentage and number of layers is very influential [7].

One form of coating that is often used in composite manufacturing is the laminate arrangement. The lamina is an arrangement of matrix and *reinforcement* in one layer. The process of forming lamina into laminate is called laminate [8], this type of laminate has a constituent laminate with unbroken fibers until it reaches the end of the lamina boundary. Composites

DOI: http://dx.doi.org/10.31963/intek.v10i2.4582

with this arrangement are most widely used in technology and industry.

[9], conducted research on the analysis of mechanical properties of sisal polyester composites using the ANOVA method concluded that the addition of fiber volume fractions can increase the mechanical strength of sisal fiber polyester composites, and also the difference in fiber direction orientation has a significant effect on the mechanical strength of sisal fiber polyester composites. [10], researching the study of mechanical properties of randomly oriented sisal fiber-reinforced epoxy composites printed with hand-lay up technique, the results showed that tensile strength and flexural strength increased with increasing fiber volume fraction with optimum value occurring at 10% fiber volume fraction. but [11], his research revealed that the tensile strength of lamina composites decreases with the increase in fiber weight fraction, in the composition of fiber weight fractions of 20% and 30% of the three specimens have been tested, an average tensile strength of 2.577 kg / mm2 and 2.251 kg / mm2 has been obtained. [12], conducted a study on the effect of fiber orientation on the tensile properties of banana fiber-reinforced polyester composites concluded that fiber orientation exerts an influence on the tensile strength of the composite, where the highest tensile stress is obtained at 0/0/0 fiber orientation and the lowest at 45/0/45.

Previous researchers showed that variations in laminate angle and the amount of fiber composition with matrices affect the mechanical strength of composite materials and have the potential to be developed today. Through these problems, analysis of the number of lamina, angular orientation, and number of sisal fibers (Agave sisalana) needs further research to obtain information to provide alternative new materials that have certain mechanical properties. Based on the explanation above, the author will analyze the comparison of mechanical strength and the influence of variations in sisal fiber composition on the tensile strength and toughness of sisal fiber lamina composite materials with the direction of combining angular variations 0/45°/90°/-45°/0° with a composition weight fraction of 5% fiber 95% (5S-95R) matrix and 15% fiber 85% matrix (15S-85R).

Composite material is a new type of engineered material consisting of two or more materials in which the properties of each material differ from each other. Based on the type of reinforcement, composites can be grouped as follows:

1. Particle composite *(Particulate Composite),* the reinforcement is particle-shaped
2. Fiber *Composite* The reinforcement is in the form of fiber
3. Structure *Composite,* a way of combining composite materials.

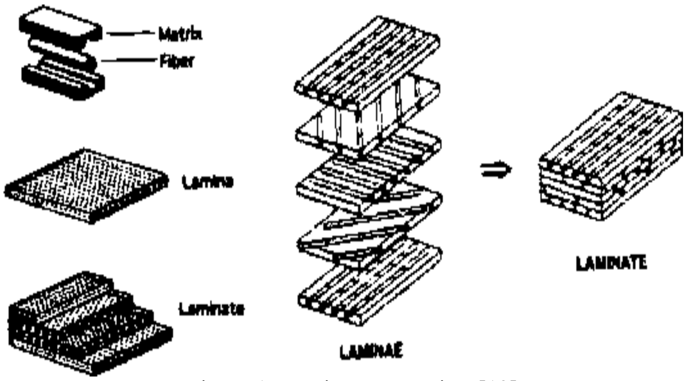

Figure 1. Lamina Composites [13]

The properties that laminate composites can improve are stiffness, lower weight, corrosion resistance, resistance to wear, and heat resistance [14]. Lamina composites have better mechanical properties than metals, and type stiffness and type strength are higher than metals. However laminate composites are very susceptible to shear stress.

Figure. 2. Agave sisalana tree

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Sisal plants are plants wich stems and leaves are fused, have strong fibers, can live on land with a thin processing layer (many surface stones), or classified as critical land, and are resistant to high salt content [4]. This plant has been cultivated en masse in various countries, such as Brazil one of the largest producers of sisal in the world, China, Kenya, Tanzania, Madagascar, Indonesia, and Thailand. The height of sisal plants ranges from 1.5–3 m when flowering, producing many bulbils and suckers. The leaves are succulent, arranged in a circular spiral with a leaf size of 75–185 cm x 10–15 cm x 2–5 cm with a black upright spiny leaf fringe and thorns up to 3 cm long). Each leaf ready for harvest produces 3–6% white fiber. Fibers are obtained through mechanical processes i.e. with a decorator device. Mature leaves are fed into a decorticator to obtain wet fibers. Furthermore, the fiber obtained is dried in the sun first before further processing. The resulting fiber contains 64–71% cellulose, 7–17% lignin, 12% hemicellulose, and 1–2% ash, with mechanical and physical properties that are density of 800–700 kg/m, water absorption 56%, tensile strength 268 MPa, modulus elasticity 15 GPa. The length of sisal fibers can vary between 1.0 – 1.5 m with diameters between 100-300 μm [15]

Polyester resin is a matrix of composites, this resin is incorporated with the thermoset resin group. Polyester resin has distinctive characteristics that are transparent, waterproof, colorable, flexible, resistant to extreme weather, and chemical resistant. The working temperature *of polyester* resin can reach 70°C or more depending on the need. The curing process in polyester can be done with the addition of catalysts [16]**.**

Mechanical properties are generally determined by destructive testing of samples of a composite under controlled loading conditions. The best mechanical properties are obtained by performing prototype testing or actual design with actual loading applications. However, specific data like this is not easy to obtain so generally standard test result data is used as published, one of which is by ASTM *(American Standard Testing and Materials).*

II. Research Methodology

2.1 Flow Chart

Design flow diagram Comparison of Tensile Test of Sisal Fiber Composite Material Lamina Matrix Polymer (Agave Sisalana).

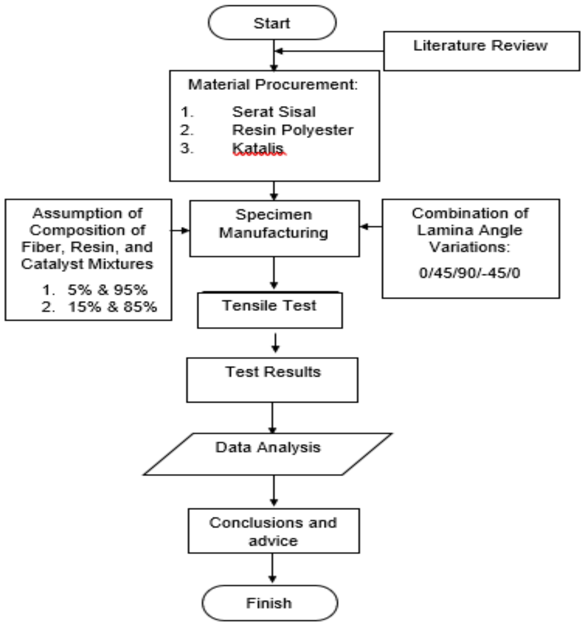

Figure. 3. Research Flow Chart

2.2 Material And Tools

The tools used in this study are tensile test equipment, molds, and other tools. The materials used in this study were sisal fiber, resin, and catalyst.

a. Tensile Testing Machine

This tensile testing machine is to determine the tensile strength of composite material specimens

Figure. 4. Shape of Tensile testing machine

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b. Mold making

The mold used is a mold made of plate iron with sizes p = 30 (cm), l = 30 (cm), and t = 1.27 (cm) so that the volume of the mold can be calculated by the equation:

$V_{Mold} = p \times l \times t$ .... (3.1)

Figure 5. Composite molding

c. Resin and Catalyst

Polyester resin is used as a matrix to make laminate composite materials and catalysts are used as additives in making dough. Resin and catalyst are poured into a measuring cup in a ratio of 100 gr resin: 1 gr catalyst. The weight fraction of the resin and catalyst can be calculated by the equation:

Resin = $\%_{polyester} \times v_{Mold} \times \rho_{polyester}$....................(3.3)

Catalyst = $\%_{katalis}$ x specific gravity of resin.........(3.4)

Figure 6. Polyester Resins and Catalysts

2.3 Completion of Specimens

For specimen preparation, there are several stages, namely: Weighing fibers according to the assumption that the composition ratio of a mixture of sisal fiber and matrix is 5% fiber 95% matrix (5S-95R), Preparing molds by coating the entire surface of the mold with mica plastic adapted to the shape of the mold, Providing measuring cups, resins, catalysts, drip pipettes, wooden spatulas, cafe, putty, gloves, clam c, and other tools, Pour the resin into a measuring cup then add catalyst 1% of the total weight of the resin then stir ± 1 minute until completely mixed, Pour the mixture into a mold of ± 300 gr then insert fibers with an orientation of $\angle 0^0$ press with a café to flatten the surface and remove the air trapped in the mold next add the dough mixture into the mold as much as ± 200 gr insert the fibers with an angle orientation of 45 press with the café, do it repeatedly until all corner orientations enter the mold, and pour all the remaining mixture of dough into the mold, flatten the surface of the dough on the mold then cover then clamped with clam c on each side of the mold, Let this mixture dry at room temperature within ± 4-5 hours so that it becomes a hard material, The dried specimen is removed from the mold and then cut to the specimen size, and clean the mold repeat process 1 - 8 for specimen preparation assuming the composition ratio of the mixture of sisal fiber and matrix is 15% fiber 85% matrix (15S-85R).

In making tensile test specimens in this study formed with sizes based on ASTM D standards 638-02 type III (*Standard Test Method for Tensile Properties of Plastics)*

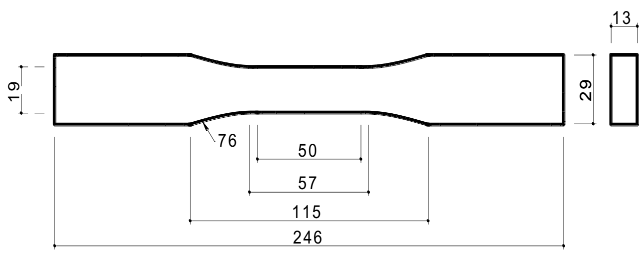

Figure 7. Specimen Dimensions for Thickness, T, mm ASTM, D 638-02 (Standard Test Method for Tensile Properties of Plastics) [17].

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III. Results and Discussion

3.1 Tensile Testing Calculation

a. cross-sectional area (A_0)

$$A_o = w\ (mm) \times t(mm)$$
$$= 19\ (mm) \times 12{,}7(mm)$$
$$= 241{,}30\ mm^2$$

b. Maximum Voltage (σ_m)

$$\sigma_m = \frac{Maximum\ load\ (N)}{cross-sectional\ area(mm^2)}$$
$$\sigma_m = \frac{5560.9598\ (N)}{241{,}30(mm^2)}$$
$$\sigma_m = 23{,}0458\ (N/mm^2)$$

c. Regangan (ε)

$$\varepsilon = \frac{lenght\ Change\ (mm)}{initial\ length\ (mm)}\ x\ 100\%$$
$$= \frac{2{,}9890\ (mm)}{50(mm)}\ x\ 100\%$$
$$= 5{,}9780\%$$

3.2. Tensile Test Discussion

a. The relationship of tensile and stretching with a composition comparison of 5% fiber and 95% resin (5S-95R).

Table. 1 composition ratio of 5% fiber and 95% resin (5S-95R).

No.	A_0 (mm^2)	Burden (N)	ΔL (mm)	s maks (N/mm^2)	ε (%)	Information
1	241,3	3062,1072	1,4945	12,6900	2,9890	Comparison of compositions 5S-95R
2	241,3	5021,8156	2,6105	20,8115	5,2210	
3	241,3	5560,9598	2,9890	23,0458	5,9780	
4	241,3	4353,2708	2,4308	18,0409	4,8615	
5	241,3	3238,2669	1,9526	13,4201	3,9052	
6	241,3	3355,0864	2,0921	13,9042	4,1843	
Average rating				16,9854	4,5232	

In table 1 of the six tensile test samples produced stress with an $_{\text{average value}}$ = 16.9854 N/mm2 and strain with an average value of ε an average of 4.5232 %.

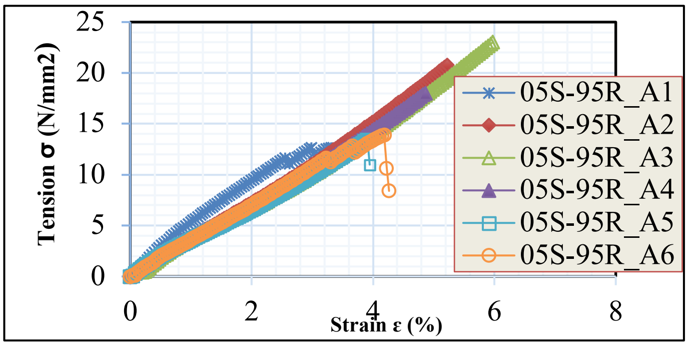

Figure. 8 .Graphic of the relationship between tensile and stretch of the composite material of the sisal fiber laminate (agave sisalana) with a comparison of the composition of 5% fiber and 95% resin (5S-95R).

Figure 8 shows the relationship between stress and strain with a composition ratio of 5% fiber and 95% resin (5S-95R), resulting in different stresses and strains, where after each specimen reaches the maximum tensile strength the material breaks.

b. The relationship of tensile and stretching with a composition comparison of 15% fiber and 85% resin (15S-85R).

Table. 2 Results of tensile testing of sisal fiber lamina composite material (agave sisalana) with a composition ratio of 15% fiber and 85% resin (15S-85R).

No.	A_0 (mm^2)	Beban (N)	ΔL (mm)	s maks (N/mm^2)	ε (%)	Information
1	241,3	10902,4996	4,8424	45,1823	9,6849	Comparison of compositions 15S-85R
2	241,3	9659,1039	4,3043	40,0294	8,6086	
3	241,3	9693,0791	4,6235	40,1702	9,2469	
4	241,3	8999,5923	4,3840	37,2963	8,7679	
5	241,3	9448,2612	4,2056	39,1557	8,4113	
6	241,3	9415,3172	4,5635	39,0191	9,1269	
Average rating				40,1422	8,9744	

In Table 2 of the six tensile test samples produced stress with $\sigma_{\text{an average value}}$ = 40.1422 N/mm2 and strain with an average value of ε an average of 8.9744 %.

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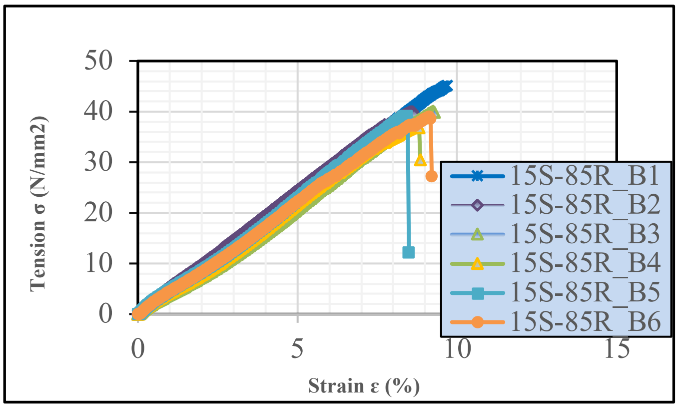

Figure. 9 Graph of the relationship between tensile and stretch of the composite material of the sisal fiber laminate (agave sisalana) with a comparison of the composition of 15% fiber and 85% resin (15S-85R).

Figure 9 shows the relationship between stress and strain with a composition ratio of 15% fiber and 85% resin (05S-95R) resulting in different stresses and strains, where after the specimen reaches the maximum tensile strength the material breaks.

In Figure 8 and Figure 9 above, it can be seen that each specimen tested produces different stresses and strain, because it does not have homogeneous properties at each point and sisal fibers have an unequal shape in each pore, causing a less perfect bond between the fiber and the matrix, causing the fibers to escape from the matrix which affects the mechanical strength of the composite.

c. Maximum tensile stress and strain relationship of sisal fiber composites

Table 3. Maximum tensile test results of sisal fiber composite with a composition ratio of 5% fiber and 95% resin (5S-95R) and composition of 15% fiber and 85% resin (15S-85R)

No.	A_0 (mm^2)	Burden (N)	ΔL (mm)	s maks (N/mm^2)	ε (%)	Information
1	241,3	5560,9598	2,9890	23,0458	5,9780	05S-95R_A3
2	241,3	10902,4996	4,8424	45,1823	9,6849	15S-85R_B1

Specimen B1 produces a maximum tensile stress of σ_m = 45.1823 N/mm2 and a maximum strain of ε = 9.6849 % with a maximum load of Fm = 10902.4996 N.

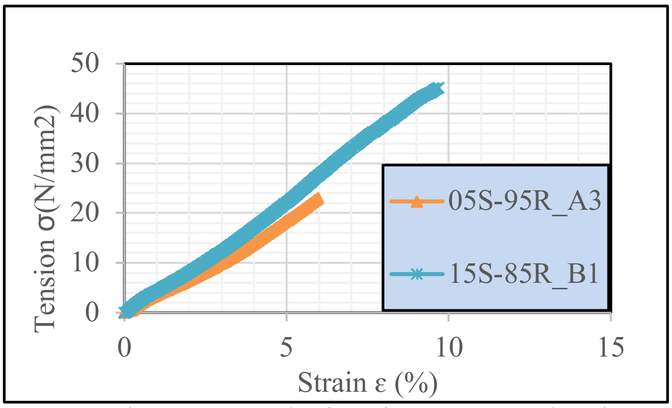

Figure 10. Graph of maximum stress and strain relationship at a composition ratio of 5% fiber and 95% resin (5S-95R) with a composition ratio of 15% fiber and 85% resin (15S-85R).

Figure 10 shows the maximum stress and strain relationship in sisal fiber lamina composite materials resulting in different stresses and strains, the higher the fiber weight fraction contained in the sisal fiber lamina composite material, the tensile stress produced increases. This shows the stress is directly proportional to the number of fibers contained in the composite.

IV. Conclusion

From the test results and calculations in this study, the mechanical properties of the combination of angular variations 0/45/90/-45/0 with a mixture composition of 5% fiber 95% resin (5S-95R) and 15% fiber 85% resin (15S-85R) can be concluded as follows:

1. The tensile test results of sisal fiber lamina composite materials with a composition ratio of 5σ% fiber 95% resinproduct maximum stress of m = 16.9854 N/mm2 and a maximum strain of ε = 4.5232% and a composition ratio of 15% fiber 85% resin produces maximum tensile stress of m = 40.1422 N/mm2 and a maximum strain of ε = 8.9744 σ %.
2. Based on the test results, the addition of the composition of the fiber mixture increases the tensile strength and toughness of the material. The composition of 5% fiber 95% and 15% fiber 85% resin (15S-85R) produces maximum tensile stress of σ_m = 45.1823 N /mm2 and a maximum strain of ε = 9.6849 % with a maximum load Fm = 10902.4996 N. And, the more fiber contained in the sisal fiber lamina

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composite material, the higher the tensile stress produced, this shows the tension is directly proportional to the number of fibers contained in the in composites.

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