# TENSILE STRENGTH STUDY OF HYBRID POLYESTER COMPOSITE MATERIAL REINFORCED WITH PINEAPPLE LEAF FIBER AND CARBONFIBER

Suksma Cahyo Aji Nugroho[1*] , Ajeng Wulansari[2] , Ade Irfansyah[3]

*[1,2,3)]Civil Aviation Polytechnics of Surabaya ,Jemur Andayani I/73 Wonocolo Surabaya, Jawa Timur, Indonesia, 60236*
**Corresponding Author Email: Suksma.nugroho@gmail.com*

**ABSTRACT**

Composites are materials made of two or more different components, which are combined to create superior or specific properties. Composite materials usually consist of a matrix and reinforcement. This research aims to study theeffect of changing the number of layers on the tensile strength of pineapple leaf fiber composites and carbon fiber composites. Pineapple leaf fiber composite is a potentially environmentally friendly material, while carbon fiber is known for its high durability. This research uses experimental research methods. The composite was made with a glass mold size of 170 x 90 x 3 mm for tensile testing by molding a mixture of resin and fiber. This research combinesnatural fibers and synthetic fibers with testing standards using ASTM D638 for tensile tests. The variables used are 1 carbon fiber, 1 pineapple leaf fiber, 1 carbon fiber; 1 carbon fiber, 2 pineapple leaf fibers, 1 carbon fiber; and 2 carbonfibers, 1 pineapple leaf fiber, 2 carbon fibers. Performed alkalization treatment to pineapple leaf fibers by soaking in 5% NaOH solution for 2 hours. The final result of the research conducted was to obtain the tensile strength results of each specimen, by obtaining the maximum tensile strength of the specimen of 152.47 Mpa and the highest strain valueof 0.130267%. For the results of the lowest elastic modulus value of 3600,713 Mpa and the highest value of 9613,392 Mpa.

***Keywords :*** *Composite, carbon fiber, pineapple leaf fiber, tensile strength*

## 1. INTRODUCTION

World civilization is developing, which has an impact on progress. There is no exception in the world technology sector, including in the aerospace sector. The rapidly evolving global aerospace world is creating a gap in dependence on man-made materials. This encourages the creation of new innovations in the development of new materials without in the development of new materials without eliminating the safety factor. Safety factors in the world of aviation are very important and crucial, one example of the material is composites. Composites have become one of the mostimportant and highly developed materials.

Composites are materials made of two or more different components, which are combined to create superior or specific properties. Composite materials usually consist of a matrix and reinforcement. The matrix is the phase that surrounds and binds the reinforcing material, while the reinforcing is the phase that imparts strength, toughness, or other properties to the composite [1].

Composites have various advantages, such as high strength-to-weight ratio, corrosion resistance, thermal insulation ability, and design flexibility. Due to these properties, composites are used in the manufacture of aircraft, space vehicles, racing cars, sports equipment, and even infrastructure such as bridges and buildings. The use of natural fibers as fillers or reinforcements in composite materials is driven by the abundance of fiber-producing plants, especially in Indonesia. Because biocomposites are made from natural materials and have a number of advantages over synthetic fibers, including being more environmentally friendly, biocomposites are growing in popularity. In addition, composites reinforced with natural fibers are lighter because the strength-to-density ratio is very high.

The use of carbon fiber in the aviation industry has a number of key advantages. These include reducing the weight of the aircraft, the ability to create complex shapes, reducing production waste, improving durability to fatigue, optimizing the design as well as increasing resistance to corrosion. In the manufacture of aircraft structures, carbon fiber is currently considered an ideal material because it has a strength comparable to that of steel alloys, while its density is only about half that of aluminum alloys [2].

Pineapple (*Ananas Comosus*) is one of the alternative fiber-producing plants that has only been used as a source of food. Based on data from the CentralStatistics Agency (BPS), the average pineapple production in Indonesia is 1.5 million tons/day. Seeing the large amount of pineapple plant production per year,of course, pineapple leaves will have great potential to become waste. In Indonesia, these plants have been widely cultivated, especially on the islands of Java and Sumatra, which are found in the areas of Subang, Majalengka, Purwakarta, Purbalingga, Bengkulu, Lampung and Palembang which is one of the natural resources that has quite potential.

Thus, it is encouraged to conduct research related to "Study on the Tensile Strength of Hybrid Polyester Composite Materials Reinforced with Pineapple Leaf Fiber and Carbon Fiber". This study aims to analyze the right number of layers in pineapple leaf fiber and carbon fiber to produce the required composite mechanical properties and has been tested for safety through a slightly different testing method, namely tensile testing. With this research, it is hoped that it can be useful for research related to composite materials.

## 1.1 Problem Formulation

Based on the description of the background of the problem above, the formulation of the problem that the author can get includes:

1. How does the number of layers affect the tensile strength of pineapple leaf fiber compositescombined with carbon fiber?
2. How does the number of layers affect the strain value and elastic modulus of pineapple leaf fiber composites combined with carbon fiber?

## 1.2 Problem Limitations

In this study, the author provides the following problem limitations:

1. These tests are carried out on a laboratory scale.
2. The test performed on the composite is a tensile test.
3. The percentage of the matrix used is the standard issued by the factory.
4. This study does not discuss the chemical bonds that occur.

## 1.3 Research Objectives

The objectives of this study are as follows:

1. To test the effect of the number of layers on the tensile strength of the composite of pineapple leaf fiber combined with carbon fiber.
2. To determine the effect of the number of layers on the strain value and modulus of elasticity of the pineapple leaf fiber composite combined with carbon fiber.

## 1.4 Benefits of Writing

The results of this study are expected to provide the following benefits:

For the Author

1. Adding the author's insight into aircraft materials to be used as a reference in the learning and application of a system.

For Educational Institutions

2. Adding constructive input to create a quality learning system about pineapple leaf fiber composite combined with carbon fiber.

# 2. RESEARCH METHODS

The flow of this research begins with a literature study to obtain information related to the topic to be researched, especially through relevant journals. Furthermore, the researcher prepared tools and materials and soaked pineapple leaf fibers with NaOH as an initial stage before making specimens. Specimen creation is carried out by paying attention to the variables to beused such as the direction of the fibers. If the test piece made fails, the manufacturing process must be repeated. If successful, the research will continue with specimen testing at the Malang State Polytechnic followed by data analysis and the preparation of results and conclusions. The detailed design of the research can be seen in figure 1.

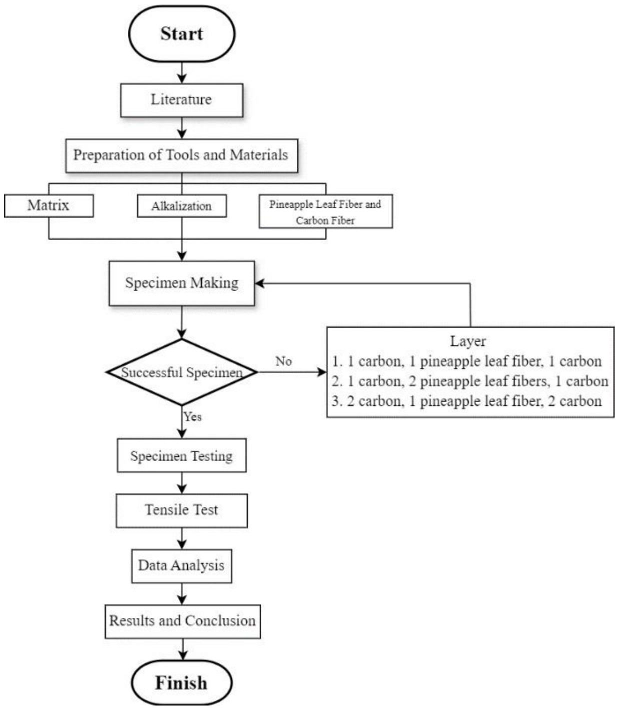


**Figure 1.** Research Flow Diagram

The method used in this study is an experimental method in making composites made of carbon fiber.This study aims to compare the percentage of catalysts with the *hand lay up* method, as shown in figure 2 [4].

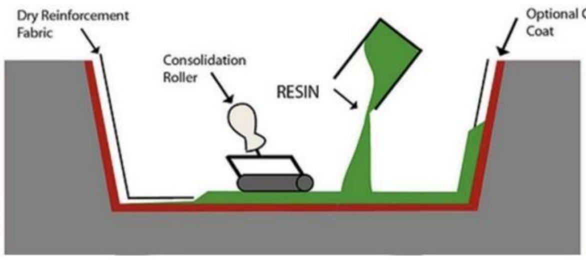


**Figure 2.** Hand lay up process

The manufacture of composites in previous studies was carried out by *hand lay-up* method which stacks layers until they reach a certain thickness [5]. Before the tensile test, a mold is made, the fiber volume fraction and catalyst percentage are determined. This method is suitable for reviewing research formulations and achieving research objectives in this final project. Previous research with similar variables also uses this method which has been proven to be appropriate and effective.

The tensile test method aims to measure the tensile strength of composites. The first step is to prepare the test piece according to the purpose of the test. Prepare the block millimeter paper on the printer to measure the change in length or elongation of the test piece. Turn on the test machine and make sure it is in good condition. Attach the test piece to the grip of the testing machine carefully, avoiding over-tightening the grip so as not to damage the surface of the object.

Once the test piece is attached, attach the extensometer to the specimen and set the elongation number to zero. Set the load number to the zero position to ensure the baseline of the test. Set the test rate according to the desired parameters, then press the start button and the down button to start the test. This process will generate data on the mechanical response of the specimen to the load. Repeat these steps on the other composites to get complete and reliable data. In this way, the test is expected to be accurate and provide important information regarding the mechanical properties of the test piece.

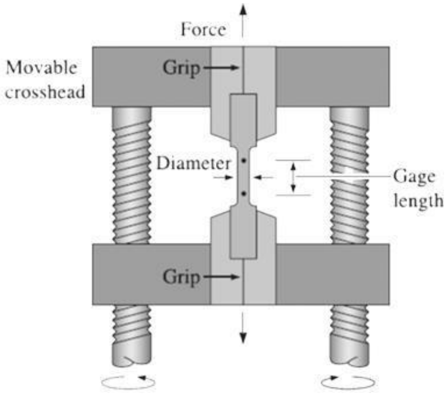


**Figure 3.** Schematic of the Tensile Test Device

From the results of the tests that have been carried out on each specimen, then calculate the tensile strength value by means of calculations that can be seen below:

Stress Formula

$$\sigma = \frac{F}{A_0} \qquad (1)$$

Information :

$\sigma$ = Stress ($N/mm^2$)

F = Loads given (N)

$A_0$ = Cross-sectional area ($mm^2$)

Strain Formula

$$e = \frac{\Delta L}{L} \qquad (2)$$

Information :

$e$ : Strain

$\Delta L$ : Length Increase (m)

L : Initial Length (m)

Modulus of Elasticity Formula

$$E = \frac{\sigma}{s} \qquad (3)$$

Information:

E : Elastic Modulus ($\gamma$)

$\sigma$ : Tegangan ($N/m^2$)

$e$ : Regangan

## 3. RESULTS AND DISCUSSION

### 3.1 Tensile Test Results

After tensile testing on composite specimens, thedata obtained will be processed to compare strengths based on the number of fibers tested. The difference in test results for each specimen is due to variations in the number of layers as well as the percentage of resin and catalyst in the composite mixture. The test results willbe presented in the form of tables and graphs.

Testing on specimen A was carried out with a mixture of 1 carbon fiber, 1 pineapple leaf fiber, and 1 carbon fiber. The results of the tensile test can be seenin table 1.

**Table 1.** Specimen A Tensile Test Results

| Spesimen | Lebar (mm) | Tebal (mm) | Luas (mm$^2$) | Beban Normal (N) | Tegangan Tarik (Mpa) |
|---|---|---|---|---|---|
| Spesimen 1 | 13,02 | 3,02 | 39,32 | 2.956,73 | 75,81 |
| Spesimen 2 | 13,01 | 3,02 | 39,29 | 2.833,12 | 72,64 |
| Spesimen 3 | 13,06 | 3,02 | 39,44 | 3123,5 | 80,08 |
| Rata-rata | | | | | 76,17 |

From the test data in the table above, in a specimen with a mixture of 1 carbon fiber, 1 pineapple leaf fiber, 1 carbon fiber, the average result of the tensile stress of specimen A was obtained which was 76.17 Mpa.

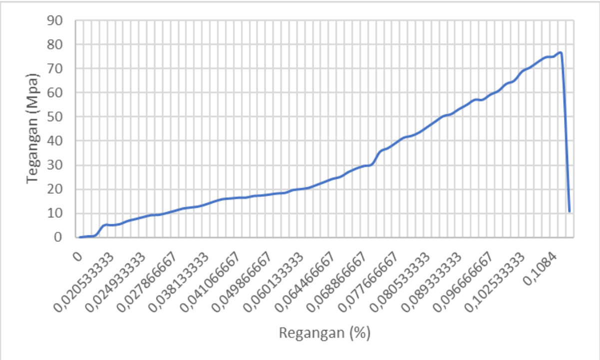


**Figure 4.** Grafik Tegangan-Regangan Spesimen A

Figure 4 shows the results of tensile strength in specimen A with a tensile value of 76.17 Mpa and a strain value of 0.1128. This result was obtained without any treatment on the composite. For the fracture results of specimen A, see figure 4.2.

**Figure 5.** Specimen A Fracture

From the test results on specimen A and analysis related to the fracture, it was found that this composite has brittle properties and is characterized by the occurrence of fiber pull out which dominates on the fault surface. Fiber pull out occurs due to the inability ofthe matrix to bind the fibers.

The test was carried out on specimen B, namely with a mixture of 1 carbon fiber, 2 pineapple leaf fibers, 1 carbon fiber which could affect the results of the tensile test of each specimen. The results of the tensile test can be seen in table 2.

**Table 2.** Specimen B Tensile Test Results

| Spesimen | Lebar (mm) | Tebal (mm) | Luas (mm$^2$) | Beban Normal (N) | Tegangan Tarik (Mpa) |
|---|---|---|---|---|---|
| Spesimen 1 | 13,02 | 3,04 | 39,58 | 3.445,27 | 88,34 |
| Spesimen 2 | 13,01 | 3,04 | 39,55 | 3.194,13 | 81,90 |
| Spesimen 3 | 13,05 | 3,04 | 39,67 | 3.351,09 | 85,92 |
| Rata-rata | | | | | 85,38 |

In contrast to the test data in the table above, in a specimen with a mixture of 1 carbon fiber, 2 pineapple leaf fibers, and 1 carbon fiber, the average result of the tensile stress of specimen B was obtained which was 85.38 Mpa.

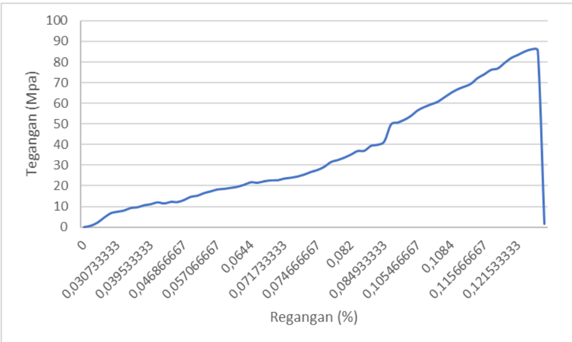


**Figure 6**. Graph of Average Yield of Specimen B

Figure 6 shows that there is a maximum increase in tensile strength with a tensile value of 85.38 Mpa and a strain value of 0.130266667 due to the addition of pineapple leaf fibers that have been treated with 5% NaOH. So that specimen B gets a better value than specimen A. Produces a fracture that can be seen in figure 7.

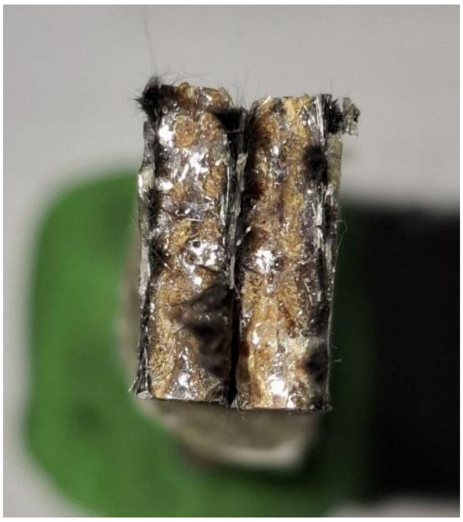

**Figure 7**. Specimen B Fracture

From the test results on specimen B and analysis related to the fracture, the same results were obtained as specimen B, that this composite has brittle properties and is characterized by the occurrence of fiber pull out that dominates on the fault surface. Fiber pull out occursdue to the inability of the matrix to bind the fibers

The test was carried out on specimen C, namely with a mixture of 2 carbon fibers, 1 pineapple leaf fiber, 2 carbon fibers which could affect the tensile test results of each specimen. The results of the tensile test can be seen in figure 7.

**Table 3.** Specimen C Tensile Test Results

| Spesimen | Lebar (mm) | Tebal (mm) | Luas ($mm^2$) | Beban Normal (N) | Tegangan Tarik (Mpa) |
|---|---|---|---|---|---|
| Spesimen 1 | 13,01 | 3,02 | 39,29 | 6.039,03 | 154,84 |
| Spesimen 2 | 13,04 | 3,02 | 39,38 | 5.711,38 | 146,44 |
| Spesimen 3 | 13,02 | 3,02 | 39,32 | 6.090,04 | 156,15 |
| Rata-rata | | | | | 152,47 |

Pada pengujian spesimen C didapatkan hasil yang lebih larger and taller than the previous two specimens. The average tensile strength in specimen C is 152.47 Mpa. The higher yield of this C specimen is due to the addition of carbon fiber and carbon fiber is still considered a strong fiber.

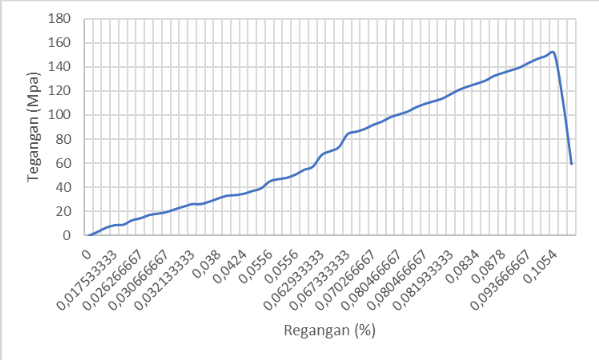


**Figure 8.** Specimen C Tension-Strain Graph

Figure 8 shows that there is a maximum increase in tensile strength with a stress value of 152.47 Mpa and a strain value of 0.1054. Produces a fracture that can be seen in figure 9.

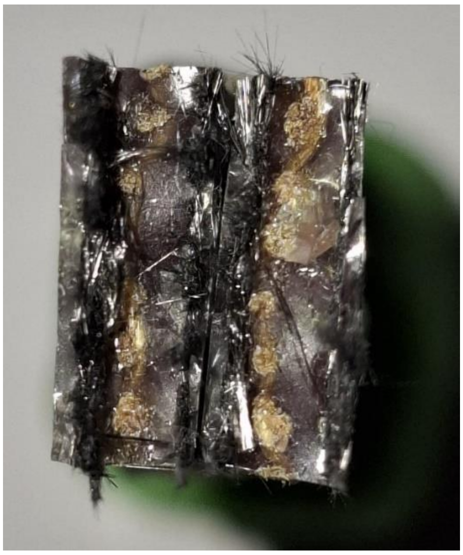

**Figure 9.** Specimen C Fracture

From the test results on specimen C and the fracture analysis, the same results were obtained as in the previous specimens. This composite exhibits brittle properties characterized by the dominance of fiber pull out on the fault surface. Fiber pull out occurs because the matrix is not able to bind the fibers properly. The amount of fibers used and the uneven distribution of fibers in the composite cause the fibers to accumulate separately during printing, leaving a lot of free space without matrix bonds.

## 3.2 Composite Tensile Strength Comparison

Based on the data from the test calculation results obtained and listed in the previous subchapter, it can be concluded that the average results of the tensile strength values of all tensile test specimens are found in table 4.4.

**Table 4.** Tensile Strength Values

| Variasi Spesimen | Nilai Kekuatan Tarik (Mpa) |
|---|---|
| Spesimen A | 76,17 |
| Spesimen B | 85,38 |
| Spesimen C | 152,47 |

In the table above, it can be seen that:

1. The highest tensile strength value obtained from the test was 152.47 MPa.
2. The lowest tensile strength value was obtained by specimen A with a value of 76.17 Mpa.

In addition to the results presented in the form of tables as above, the results are also presented in the form of graphs to make the results easier to understand. The graph presented can be seen in figure 10.

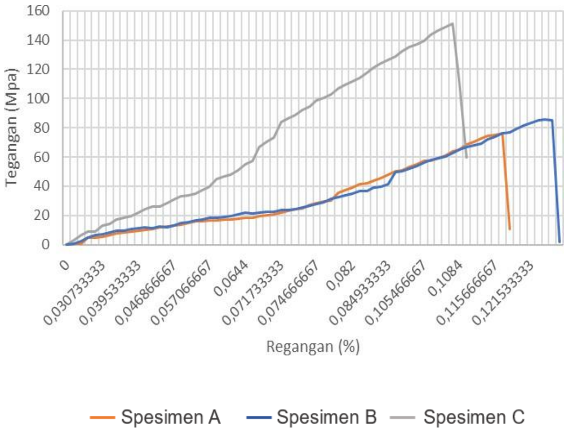


**Figure 10.** Whole Variable Tension-Strain Graph

From the graph above, some differences can be seen in the three variations of the specimens tested The first difference is seen between specimens A and B where specimen A has a longer strain than specimen B although the voltage difference is not very large An increase in voltage in specimen B may occur due to the addition of pineapple leaf fibers that have undergone an alkalisation treatment which contributes to a significant increase in tension and strain Specimen C Next shows a fairly high maximum tensile strength, almost double the tensile strength of specimens A and B with a tensile value of 15247 MPa, however, specimen C has a lower strain compared to other specimens, only reaching 01054 The high tension in specimen C is due to the larger composition of carbon fiber, which is known to have high strength and light weight, Specimen C showsa higher tensile strength due to the addition of Carbon fiber which proves that carbon fiber remains one of the strongest artificial fibers even with the addition of twice the amount of natural fibers The composite has not beenable to surpass the strength of the composite with acarbon matrix This material has an excellent strength-to-weight ratio making it superior in a wide range of applications In addition, the material is resistant to high heat and has corrosion resistance, especially when used with resins that Its good flexibility also makes it suitable for a wide variety of uses Conclusion of tensile testing on the entire specimen shows that the addition of natural fibers can increase the elasticity and strain of the composite while the addition of artificial fibers can increase the maximum stress of the composite Therefore, to obtain a composite with optimal results at stress and strain it is necessary to have the right composition between natural fibers and artificial fibers so that created a strong, lightweight and flexible composite

## 3.3 Comparison of Strain Value and Modulus of Elasticity

Based on the data from the test calculation results obtained and listed in the previous sub-chapter, the results of the strain values are obtained which are listed in the form of table 5.

**Table 5.** Strain Values

| Variasi Spesimen | Nilai regangan (%) |
|---|---|
| Spesimen A | 0,1128 |
| Spesimen B | 0,130267 |
| Spesimen C | 0,1054 |

From the results of the comparison of the strain values obtained, it is actually proportional to the results of the tensile stress. If the stress value is obtained, the maximum strength is in specimen C, but for the maximum strain value this is actually in specimen B. The strain value in specimen B has a maximum value of0.130267%. The high strain value in specimen B was obtained due to the addition of pineapple leaf fiber,which proves that this pineapple leaf fiber has elastic properties. In the C specimen to which carbon fiber was added, it turned out that it could not support its stretch value, which can be concluded that this carbon fiber is brittle.

Based on the data from the test calculation results obtained later and listed in the previous sub-chapter, the results of the modulus of elasticity are obtained which are listed in the form of table 6.

**Table 6.** Modulus of Elasticity Values

| Variasi Spesimen | Modulus Elastisitas (Mpa) |
|---|---|
| Spesimen A | 3837,407 |
| Spesimen B | 3600,713 |
| Spesimen C | 9613,392 |

From the results of the calculation of the modulus of elasticity of each variation, a considerable differencewas obtained from each variation. Specimen A got a value of 3837,407 Mpa, specimen B got a value of 3600,713 Mpa, and specimen C got a value of 9613,392 Mpa. From these results, it is known that the specimen with the smallest value is included in elastic materials. Thus, specimen B is the most elastic variation comparedto other variations and specimen C is the most plastic variation compared to other variations. It can be concluded that by adding the composition of pineapple leaf fibers to the composite material, the material becomes more elastic than just using artificial fibers.

## CONCLUSION

Based on the results of the research that has been carried out regarding the influence of layer variations on the tensile test of carbon fiber hybrid composite with pineapple leaf fiber, it can be concluded as follows:

1. Based on the results of tensile tests that have been carried out on the three variations in the number of layers used, it is known that the composite with a composition of 2 carbon fibers, 1 pineapple leaf fiber, 2 carbon fibers is the specimen that has the highest strength result out of all the variations ofthe tested specimen with a value of 152.47 Mpa. The results obtained are a factor in the addition of carbon fiber, for the pineapple leaf fiber itself only provides a little strength to support the composite tobecome stronger.
2. Based on the results of the calculation of strainvalues and elasticity modulus values of hybrid composite specimens. The highest strain value was obtained by specimen B with a value of 0.130267%. For the elastic modulus value, the lowest value was owned by specimen B with a value of 3600,713 Mpa and the highest value was owned by specimen C with a value of 9613,392 Mpa. It can be concluded that of these three specimen variations, which include elastic material,namely specimen B and the plastic material is specimen C. Factors that affect the tensile strength of composite specimens include uneven arrangement of fibers as well as damage to carbon fibers when installed in molds can reduce the structural integrity of composites. The difference in fiber type also contributes to the variation in tensile strength, where natural fibers, although environmentally friendly, have not been able to match the strength of artificial fibers. Finally, manual manufacturing often does not result in a perfect mold, affecting the overall quality of the specimen.

## REFERENCES


[1] Beliu, H. N., Pell, Y. M., Jasron, J. U., Jurusan, ), & Mesin, T. (2016). Analisa Kekuatan Tarik dan Bending pada Komposit Widuri-Polyester. http://ejournal-fst-unc.com/index.php/LJTMU

[2] Patel, K. S., Shah, D. B., Joshi, S. J., & Patel, K. M. (2023). Developments in 3D printing of carbon fiber reinforced polymer containing recycled plastic waste: A review. Cleaner Materials, 9, 100207. https://doi.org/10.1016/j.clema.2023.100207

[3] Yasa Utama, F., Zakiyya, H., Teknik Mesin, J., Teknik, F., & Negeri Surabaya, U. (2016). Pengaruh variasi arah serat Komposit Berpenguat Hibrida Fiberhybrid Terhadap Kekuatan Tarik dan Densitas Material Dalam Aplikasi Body Part Mobil. In mekanika (Vol. 15, Issue 2).

[4] Perwara, A. S., Teknik, J., Udara, P., Penerbangan, T., Surabaya, P., & Jemur Andayani, J. (n.d.). PENGARUH PERSENTASE KATALIS TERHADAP SIFAT MEKANIS KOMPOSIT BERMATRIK RESIN POLYESTER.

[5] Triyono. (2019). Perancangan dan Pembuatan Cetakan Komposit Untuk Metode Vacuum Infusion Menggunakan Penekan Elastomer Bag.

[6] Rahmanto, M. (2019). *ANALISA KEKUATAN TARIK DAN IMPAK KOMPOSIT BERPENGUAT SERAT KELAPA DAN TEBU DENGAN PERENDAMAN NaOH DAN MENGUNAKAN RESIN POLYESTER*.

[7] Maryanti, B., & As'ad Sonief, ) A. (2011).Pengaruh Alkalisasi Komposit Serat Kelapa- Poliester Terhadap Kekuatan Tarik. In *Jurnal Rekayasa Mesin* (Vol. 2, Issue 2).

[8] Rajesh, G., Siripurapu, G., & Lella, A. (2018). Evaluating Tensile Properties of Successive Alkali Treated Continuous Pineapple Leaf Fiber Reinforced Polyester Composites. In *Materials Today: Proceedings* (Vol. 5). www.sciencedirect.comwww.materialstoday.com/proceedings

[9] Artha Wirawan, W., Dwi Widodo, T., Zulkarnain, A., Perkeretaapian Indonesia, A., Tirta Raya, J. I., Lor, N., & Harjo, M. (2018). ANALISIS PENAMBAHAN COUPLING AGENT TERHADAP SIFAT TARIK BIOKOMPOSIT KULIT WARU (HIBISCUS TILIACEUS)-POLYESTER. *Jurnal Rekayasa Mesin*, 9(1), 35–41.

[10] Hosseini, S. S. (2018). *New types of resins and their application Resin | Resin Types Specifications of resin.* https://www.researchgate.net/publication/336724301

[11] Subagyo, M. I. A., & Muchsin, R. (2024). Pengaruh Fraksi Volume Dan Susunan Serat Komposit Polyester-Serat Eceng Gondok Terhadap Nilai Konduktivitas Termal. JTAM ROTARY, 6(1), 71–84. https://doi.org/10.20527/jtamrotaryv7ì1.216