# The Effect of Banana Stem Fiber Mixtures on Mechanical and Physical Properties Using a Polyester and Vinylester Blend Matrix

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***Abstract.***
*Natural fiber-reinforced composites continue to be developed as lightweight, economical, and environmentally friendly alternatives to metals and synthetic composites. One natural fiber with strong potential is banana stem fiber, which is easily obtained and helps reduce environmental waste. This study aims to determine the effect of adding banana stem fiber on the mechanical and physical properties of a composite using a mixed matrix of polyester resin (70%) and vinylester resin (30%). The composites were fabricated using the hand lay-up method with fiber mass variations of 0, 2, 5, 7, and 12 grams, and were subsequently tested for impact strength according to the ASTM D6110 standard. The results show that the addition of banana stem fiber significantly increased the impact strength of the composite. The specimen without fiber (0 grams) produced the lowest absorbed energy and impact strength values, while the 12-gram fiber variation showed the best performance, with an average absorbed energy of 11.66 Joules and the highest impact strength of 0.090 J/mm². Variations in values among specimens of the same composition are presumed to result from the hand lay-up fabrication process, such as uneven fiber distribution and the formation of voids. Overall, the composite with 12 grams of banana stem fiber in a 70% polyester–30% vinylester matrix was identified as the best composition in this study.*
***Keywords****: composite, banana stem fiber, polyester, vinylester, hand lay-up and impact strength.*

## I. INTRODUCTION

In Indonesia, composites from natural fibers have been developed. One example is banana stem fiber, an alternative natural fiber material for scientific composite production. Its use continues to be developed in the automotive and textile industries. Banana stem fiber is gaining popularity because it is readily available and can reduce environmental waste. This composite can alleviate environmental problems, is renewable, and is safe for health.[1].

Based on the type of reinforcement, the composite in this study is a fiber reinforced composite because it uses banana stem fiber as the main reinforcement. Judging from the type of fiber, this composite is classified as a natural fiber composite, because banana stem fiber comes from a natural source, is environmentally friendly, and has the potential to improve the mechanical properties of the composite when combined with a suitable matrix. Meanwhile, based on the type of matrix, this composite is classified as a polymer matrix composite, because it uses a mixture of polyester and vinylester matrices that function to bind the fibers, increase interfacial bonds, and influence the mechanical and physical properties of the resulting composite.[2].

The use of natural fiber-based composite materials (natural fiber composites) is increasingly developing as an alternative to synthetic materials (fiberglass) that are environmentally friendly and economical. Banana stem fiber is an agricultural waste that has high potential as a composite reinforcement because it has a high cellulose content. One of the obstacles of natural fibers is their hydrophilic nature (absorbs water) and low adhesion to the matrix, so the right matrix combination is needed. Polyester resin is often used because it is cheap, but has limited mechanical strength.[3].

*Vinylester*has better water resistance and mechanical strength than polyester. Therefore, this study aims to combine the two matrices (polyester-vinylester mixture) to improve the adhesion of banana stem fibers, while studying the effect of variations in fiber volume fraction on mechanical strength (tensile/bending/impact) and physical properties of density/water absorption. The use and utilization of composite materials is now in line with the increasing use of composite materials that are increasingly widespread, for example, household appliances, electrical equipment, car components, to the industrial sector, both small-scale and large-scale industries.

This study used banana stem fiber, which is underutilized by the community. This study was conducted to obtain data on the mechanical and physical properties, namely impact strength and tensile strength of banana stem fiber composites with a vinylester (phenolic) matrix with variations in banana stem fiber washing time using K (OH) chemical solution and temperature during testing and made using the most basic engineering methods. It is hoped that this research will be useful in household life and the world of manufacturing and automotive industries.

## II. RESEARCH METHODS

This research was conducted inMechanical Engineering Laboratory, Caltex Riau Polytechnic. This location was selected based on the availability of adequate facilities and equipment for conventional lathe processing and surface roughness measurements. The research is planned to last seven months, from February 2026 to August 2026, covering the preparation stage, conducting experiments, collecting data, analyzing data, and compiling research results..

**General Design or Case Study**

This research is an experimental study aimed at determining the effect of using banana stem fiber as a reinforcing material on the mechanical and physical properties of composite materials using a mixture of polyester and vinylester matrices. The focus of the research is directed at the effect of variations in fiber and matrix composition on the performance of the resulting composite.

The research began with the design and fabrication of composite specimens using banana stem fibers in various fractions or percentages, along with predetermined ratios of polyester and vinylester matrices. The specimen fabrication process was carried out using controlled methods to obtain a homogeneous composite that met testing standards.

**Research Design Method**

The research design is a stage designed to describe in detail and systematically the flow of research implementation, starting from the preparation stage to the data analysis process. The purpose of this method is to ensure that the research can be carried out in a planned, controlled manner, and in accordance with the desired objectives, namely to determine the effect of the use of a mixture of banana stem fibers on the mechanical and physical properties of composites with a mixture of polyester and vinylester matrices.

This study used an experimental method. This method was carried out by making banana specimens with a mixture of polyester and vinylester composite stem fiber matrix, then providing variations in fiber composition and matrix ratio. Next, the specimens were tested in the laboratory to determine mechanical properties (impact test) and physical properties (density and water absorption). The test data were analyzed quantitatively to determine the effect of composition variations on the characteristics of the composite.

**Experimental Design and Specimen Planning**

The experimental design was designed to determine variations in material composition and the number of test specimens for each variation studied. This planning aimed to ensure that the test data obtained had a high level of accuracy and could objectively represent the material's characteristics. Therefore, more than one test specimen was created for each composition variation to minimize measurement error and increase the reliability of the research results.

In this study, composition variations focused on the percentage of banana stem fiber as a reinforcing material and the composition of the polyester and vinylester resin matrices. These variations were designed to determine the effect of changes in fiber content and matrix type on the mechanical and physical properties of the resulting composite. With this experimental design, the relationship between material composition and composite characteristics can be systematically observed and measured.

Table1Composite Specimen Variation Table

| No | Banana Stem Fiber (Gram) | Polyester & vinylerter (70;30%) | Specimen Code |
|---|---|---|---|
| 1 | 0 | 100 | PV0 |
| 2 | 2 | 100 | PV2 |
| 3 | 5 | 100 | PV5 |
| 4 | 7 | 100 | PV7 |
| 5 | 12 | 100 | PV12 |

Impact Testing Procedures and Data Obtained

Impact testing was conducted using a Charpy impact testing machine according to ASTM D6110 standards. Data obtained from this test include:

1. Initial angle of the pendulum ($\theta_1$) – read from the machine scale before the pendulum is released
2. The final angle of the pendulum ($\theta_2$) – is read from the machine scale after the pendulum strikes and passes through the specimen.
3. Absorbed energy (E) in Joules – calculated from the formula or read directly from the digital machine
4. Broken cross-sectional area (A) in $mm^2$ – measured using a caliper after the specimen breaks, with the formula: $A = width \times thickness$ of the specimen
5. Impact strength (aI) in $J/mm^2$ – calculated from: $aI = E / A$
6. All test data were then summarized and analyzed to determine the effect of variations in the volume fraction of banana stem fiber on the material's ability to absorb impact energy.

**Composite Specimen Manufacturing Procedure**

The manufacture of composite specimens in this study was carried out usingmethod**hand lay-up**This method was chosen because it has a simple procedure, relatively low cost, and is easy to apply to small-scale laboratory research.

## III. DATA ANALYSIS AND RESULTS

**Specimen Discussion Results**

The specimens in this study were made using the casting method with Testing was carried out using the Charpy method according to the ASTM D6110 standard with five variations of the composition of the mixture of polyester resin and vinylester resin, namely 70%: 30%, and a mixture of banana stem fibers, namely 0.2 grams, 5 grams, 7 grams and 12 grams. Before the mixing process, the mold was cleaned and coated using a release agent so that the specimens were easily removed after the curing process.

The composite specimens were made using the hand lay-up method with banana stem fiber reinforcement and a matrix of a mixture of polyester resin and vinylester resin (70%:30%). The fiber fraction variations used were 0.2 grams, 5 grams, 7 grams, and 12 grams according to the research design.

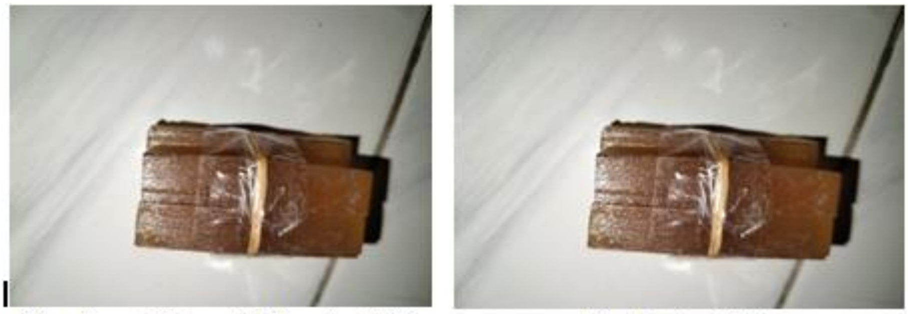
The process begins with cleaning the mold to allow the specimen to be easily removed after hardening. Banana stem fiber is weighed according to the specified variation, then polyester resin and vinylester resin are mixed until homogeneous. The MEKP catalyst is then added and the mixture is gently stirred before being poured into the mold containing the fiber. The composite is then cured at room temperature until it hardens.

After the curing process was complete, the specimens were removed from the molds and subjected to a finishing process to remove any remaining resin and adjust their dimensions to meet impact testing standards. Observations showed that all specimens had good shape, relatively flat surfaces, and uniform dimensions. Although some small air bubbles were still present, their number was insignificant and did not affect the specimens' suitability as test objects.

Overall, the resulting specimens have met the testing requirements and are ready to be used to analyze the effect of variations in banana stem fiber fractions on the mechanical properties of composites through impact testing.

**Fig 1** polyester and vinylester measurements

Based on the weighing, mixing, and molding of materials according to the designed composition, composite specimens were successfully produced for each research variation. Documentation of the specimen creation results for each composition variation is presented in the following section:



Mixed variation of Polyester 70% Vinylester 30%

**Impact Test Results**

**4.2.1 Implementation of Impact Testing**

Impact testing in this study aims to determine the ability of banana stem fiber composites to absorb energy due to shock loads, thereby determining the level of toughness of the resulting material. Testing was conducted using the Charpy method in accordance with the ASTM D6110 standard, as described in Chapter II and the research procedure in Chapter III.

Before testing, each specimen is inspected to ensure its dimensions, surface condition, and quality meet the test requirements. Specimens free from defects such as cracks or deformation are then mounted on a horizontal impact testing machine stand according to the Charpy method. The pendulum is then released until it hits the center of the specimen, causing it to fracture due to shock loading.

The data obtained from the test includes the absorbed energy (E) read from the impact testing machine, then used to calculate the impact strength value based on the fracture cross-sectional area of the specimen. Data processing is carried out using the equation explained in Chapter II to obtain the toughness value of each composite variation.

To obtain more accurate and reliable results, each variation of banana stem fiber fraction was tested using several specimens. The test results from each specimen were then averaged and used as a basis for analyzing the effect of fiber content variations on the composite's ability to absorb impact energy. The test results were then presented in tabular form and discussed to determine the relationship between banana stem fiber composition and the mechanical properties of the resulting composite.

**4.2.2 Impact Test Data**

The test was conducted using an impact testing machine according to ASTM D6110 standards. The primary data obtained from the test was the absorbed energy (E), which was used as the basis for calculating the impact strength of each specimen variation. This value was then analyzed to determine the effect of the addition of banana stem fiber fractions on the composite's ability to absorb energy due to shock loading.

All test results from each composition variation were then summarized, the average value calculated, and presented in tabular form as a basis for analyzing the relationship between variations in banana stem fiber fractions and the mechanical properties of the composite. The impact test results for each specimen variation are shown in Table 4.1.

Table 1 Impact Test Result Data

| Resin and Fiber Mix Variations | Specimen 1 (J) | Specimen 2 (J) | Specimen 3 (J) | Average (J) |
|---|---|---|---|---|
| Polyester 70% vinylesteer 30% With 0 G Fiber | 1 | 1 | 1 | 1.00 |
| Polyester 70% vinylesteer 30% With 2 G Fiber | 1 | 5 | 2 | 2.66 |
| Polyester 70% vinylesteer 30% With 5 G Fiber | 10 | 4 | 4 | 6 |
| Polyester 70% vinylesteer 30% With 7 G Fiber | 8 | 8 | 10 | 8.66 |
| Polyester 70% vinylesteer 30% With 12 G Fiber | 3 | 12 | 20 | 11.66 |

Based on Table 4.1 above, it can be seen that the impact absorption energy value increases with the increasing amount of banana stem fiber in the composite. The specimen without fiber (0 g) has the lowest average absorption energy value, namely 1.00 Joules, while the highest value is obtained in the 12 g fiber variation with an average of 11.66 Joules. These results indicate that the addition of banana stem fiber increases the composite's ability to absorb impact energy before it fractures.

The increase in absorption energy indicates that the banana stem fiber acts as a reinforcing material, helping to withstand and distribute the load throughout the composite matrix. However, there are differences in values across several specimens within the same variation. This is thought to be influenced by uneven fiber distribution, the formation of air cavities or the manual lay-up process of making specimens. Overall, the test results show that the greater the fraction of banana stem fiber used, the higher the impact absorption energy of the composite. This data is then used as a basis for calculating impact strength and analyzing the effect of fiber addition on the mechanical properties of the composite.

**Calculation of Impact Test Value**

After the absorption energy data is obtained from the impact test results, the next step is to calculate the impact strength value for each specimen variation. The calculation is carried out usingEquation (2.7)which was explained in Chapter II.

$$HI = \frac{\mathrm{E}}{\mathrm{A}}$$

Information:

HI = Impact value (J/mm2)

E = Absorbed energy (J)

A = Cross-sectional area of the specimen (mm2)

In this study, the cross-sectional size of the specimen is

Width = 12.7 mm

Thickness = 10.16 mm

So that the cross-sectional area of the specimen is obtained.

A = 12.7 × 10.16

A = 129.03 $mm^2$

Next, the impact value is calculated for each specimen as follows.

1. Variation of Polyester 70%, Vinylester 30% With Fiber 0 (G)

Specimen 1: $HI = \frac{1}{129{,}03}$= 0.007 J/$mm^2$

Specimen 2: $HI = \frac{1}{129{,}03}$=0.007 J/$mm^2$

Specimen 3: $HI$= =0.007 J/$\frac{1}{129{,}03}mm^2$

Based on the calculation results, the impact strength values for the three specimens with a mixture of 70% polyester resin, 30% vinylester resin, and without the addition of fiber (0 g) were each 0.007 J/mm². The same values for all specimens indicate that the test results have a good level of consistency and the material's ability to absorb impact energy is relatively uniform. The low impact strength value in this variation indicates that the matrix without fiber reinforcement has limited toughness against shock loading. This indicates that the addition of fiber as a reinforcing material is needed to increase the composite's ability to absorb impact energy and resist fracture due to impact.

2. Variation of Polyester 70%, Vinylester 30% With Fiber 2 (G)

Specimen 1: $HI = \frac{3}{129{,}03} = 0{,}023 \text{ J}/mm^2$

Specimen 2: $HI = \frac{5}{129{,}03} = 0.038 \text{ J}/mm^2$

Specimen 3: $HI = \frac{2}{129{,}03} = 0.015 \text{ J}/mm^2$

The results of the calculations above show that the impact strength values of specimens with a mixture of 70% polyester resin, 30% vinylester resin, and the addition of 2 g of banana stem fiber are 0.023 J/mm², 0.038 J/mm², and 0.015 J/mm², respectively. The differences in the values in the three specimens indicate variations in the composite's ability to absorb impact energy. These variations are thought to be influenced by the fiber distribution that is not yet completely even, the formation of air cavities, and differences in the quality of the bond between the fiber and the matrix during the specimen manufacturing process. However, the impact strength values in the 2 g variation are generally higher than the specimen without fiber (0 g). This indicates that the addition of banana stem fiber begins to contribute as a reinforcing material so that the composite's ability to withstand shock loads and absorb impact energy increases.

3. Variation of Polyester 70%, Vinylester 30% With Fiber 5 (G)

Specimen 1: $HI = \frac{10}{129{,}03} = 0.077 \text{ J}/mm^2$

Specimen 2: $HI = \frac{4}{129{,}03} = 0.031 \text{ J}/mm^2$

Specimen 3: $HI = \frac{4}{129{,}03} = 0{,}031 \text{ J}/mm^2$

The results of the calculations above show that the impact strength values of specimens with a mixture of 70% polyester resin, 30% vinylester resin, and the addition of 5 g of banana stem fiber are 0.077 J/mm², 0.031 J/mm², and 0.031 J/mm², respectively. These results indicate that the composite's ability to absorb impact energy has increased compared to variations in the addition of 2 g of fiber or specimens without fiber. The highest impact value was obtained in the first specimen, while the second and third specimens had the same value. The difference in values between specimens is thought to be caused by the distribution of fibers that is not yet completely homogeneous, the presence of air cavities and variations in the quality of the bond between the fiber and the matrix during the fabrication process. Overall, the addition of 5 g of fiber provides an increase in composite toughness, which indicates that banana stem fiber is able to strengthen the matrix and increase the material's ability to absorb impact energy before breaking.

4. Variation of Polyester 70%, Vinylester 30% With Fiber 7 (G)

Specimen 1: $HI = \frac{8}{129{,}03} = 0.062 \text{ J}/mm^2$

Specimen 2: $HI = \frac{8}{129{,}03} = 0.062 \text{ J}/mm^2$

Specimen 3 ; $HI = \frac{10}{129{,}03} = 0.077 \text{ J}/mm^2$

The results of the calculation of the above values of impact strength on specimens with a mixture of 70% polyester resin, 30% vinylester resin, and the addition of 7 g of banana stem fiber are respectively 0.062 J/mm², 0.062 J/mm², and 0.077 J/mm². These results indicate that the composite has a better ability to absorb impact energy compared to variations with lower fiber additions. Two specimens produced the same impact value, while one specimen showed a higher value. This difference is thought to be influenced by the level of fiber distribution, the quality of the bond between the fiber and the matrix, and the possibility of formation*void*during the fabrication process. Overall, the addition of 7 g of fiber increased the composite's toughness, making the material more effective at resisting shock loads and preventing fractures from impact.

5. Variation of Polyester 70%, Vinylester 30% With Fiber 12 (G)

Specimen 1: $HI = \frac{3}{129{,}03} = 0.023\ J/mm^2$

Specimen 2: $HI = \frac{12}{129{,}03} = 0.093\ J/mm^2$

Specimen 3 ; $HI = \frac{20}{129{,}03} = 0.155\ J/mm^2$

The results of the calculation of the above values of impact strength on specimens with a mixture of 70% polyester resin, 30% vinylester resin, and the addition of 12 g of banana stem fiber are respectively 0.023 J/mm², 0.093 J/mm², and 0.155 J/mm². These results indicate that the 12 g variation produces the highest impact strength value compared to other fiber addition variations, which indicates that the addition of banana stem fiber is able to increase the toughness of the composite in absorbing impact energy. However, there is a fairly large difference in values between specimens, especially in the first specimen which has a lower value than the second and third specimens. This difference is thought to be caused by a less homogeneous fiber distribution, the formation ofcavities and variations in the bond quality between the fiber and the matrix during the fabrication process. Overall, the test results showed that the addition of 12 g of fiber increased the composite's ability to withstand shock loads, resulting in better impact resistance compared to previous fiber addition variations.

**Impact Test Average Value**

Based on Table 4.2 below, the addition of banana stem fiber to the composite with a mixture of 70% polyester resin and 30% vinylester resin is proven to increase the average impact value. The specimen without fiber (0 g) has the lowest impact value of 0.007 J/mm², which indicates that the ability to absorb impact energy is still low because the resin matrix tends to be brittle. After adding 2 g, 5 g, and 7 g of fiber, the impact value increased successively to 0.025 J/mm², 0.046 J/mm², and 0.067 J/mm². This increase indicates that the fiber functions as a reinforcement that helps absorb and distribute impact energy so that the composite's toughness is improved.

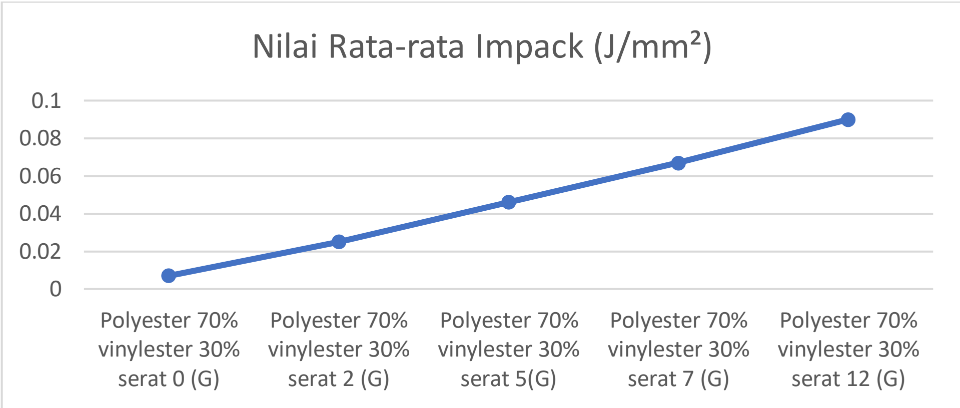
The highest impact value was obtained with the addition of 12 g of fiber, at 0.090 J/mm². This result indicates that this variation has the best ability to withstand shock loads. Overall, the greater the addition of banana stem fiber, the higher the composite's impact value, thus increasing the material's resistance to impact.

Table 2 Average Impact Values

| Resin and Fiber Mix Variations | Average Impact Value (J/mm²) |
|---|---|
| Polyester 70% vinylester 30% fiber 0 (G) | 0.007 |
| Polyester 70% vinylester 30% fiber 2 (G) | 0.025 |
| Polyester 70% vinylester 30% 5(G) fiber | 0.046 |

| | |
|---|---|
| Polyester 70% vinylester 30% fiber 7 (G) | 0.067 |
| Polyester 70% vinylester 30% fiber 12 (G) | 0.090 |

**Impact Test Average Graph**




Based on the graph above, the average impact test value shows a consistent increasing trend as the amount of banana stem fiber in the composite with a mixture of 70% polyester resin and 30% vinylester resin increases. Specimens without fiber addition (0 g) produce the lowest impact value of 0.007 J/mm², while the addition of 2 g, 5 g, and 7 g of fiber increases the impact value to 0.025 J/mm², 0.046 J/mm², and 0.067 J/mm², respectively. The highest impact value is obtained in the variation of 12 g fiber addition, which is 0.090 J/mm². These results indicate that the addition of banana stem fiber is able to increase the composite's ability to absorb impact energy. Fiber acts as a reinforcing material that helps distribute shock loads, thereby inhibiting crack propagation and increasing material toughness.

Overall, the graph shows a direct relationship between the amount of banana stem fiber and the average impact test value. Thus, it can be concluded that the addition of fiber up to 12 g in a mixture of 70% polyester resin and 30% vinylester resin provides the best impact performance, so that this variation is the most effective composition in increasing the composite's resistance to impact loads.

**4.2.6 Discussion of Impact Test Results**

The results of the impact tests that have been carried out, it is known that the addition of banana stem fiber to the composite with a mixed matrix of 70% polyester resin and 30% vinylester resin provides a tendency to increase the impact strength value. The average impact strength value increased from 0.007 J/mm² in specimens without fiber to 0.025 J/mm², 0.046 J/mm², 0.067 J/mm², and reached the highest value of 0.090 J/mm² in the variation of the addition of 12 g of fiber. These results indicate that in the range of variations studied, the greater the amount of banana stem fiber added, the higher the composite's ability to absorb impact energy before breaking.

The increase in impact strength indicates that the banana stem fibers function as a reinforcing material, working in conjunction with the matrix to absorb shock loads. When the specimen is impacted, the energy received is not only retained by the resin matrix but also transmitted to the fibers through the interfacial bond between the fibers and the matrix. This mechanism results in a more even stress distribution, thereby slowing the rate of crack propagation. Consequently, the composite requires more energy to fail, thus increasing its impact strength.

Specimens without fiber reinforcement produced the lowest impact strength because their impact-resistance capabilities depended solely on the composite matrix of polyester and vinylester resins. Although both resins function as binders and structural members of the composite, the matrix without fiber reinforcement had a more limited ability to inhibit crack propagation. Conversely, in specimens containing banana stem fiber, the fibers played a role in supporting the load and reducing stress concentrations in the matrix, thus improving the composite's toughness.

The 12g fiber addition variation produced the highest impact value of 0.090 J/mm². This result indicates that the fiber amount in this variation is still well distributed in the matrix so that the load transfer process takes place more effectively. In addition, the mixture of 70% polyester resin and 30% vinylester resin provides a fairly good bond to the fibers, so that impact energy can be absorbed more optimally before the specimen fractures. Based on the results of this study, the 12g variation is the best variation of all the compositions tested.

Differences in impact values across multiple specimens within the same variation are thought to be influenced by the hand-layup composite manufacturing process. This method relies heavily on precision during mixing, fiber arrangement, and molding. Inhomogeneous fiber distribution, the formation of air bubbles, and differences in resin distribution can affect the bond quality between the fibers and the matrix. These conditions result in varying impact energy absorption capabilities for each specimen, even when using the same material composition.

The results of this study align with composite theory, which states that adding fiber as a reinforcing material can improve the mechanical properties of a material, particularly its impact toughness. Fibers serve as the primary load-bearing component, while the matrix binds the fibers, maintains the composite's shape, and transfers stress from the matrix to the fibers. Therefore, the more effective the bond between the fibers and the matrix, the better the composite's ability to absorb impact energy.

Overall, the results of the study indicate that the addition of banana stem fiber to the composite with a mixture of 70% polyester resin and 30% vinylester resin provides an increase in impact strength. Within the range of variations studied, the addition of fiber up to 12 g produces the highest impact strength value of 0.090 J/mm², so that this variation can be stated as the best variation in this study because it has the highest ability to absorb impact energy.

## IV. CONCLUSION

Based on the results of research on the effect of banana stem fiber mixture on the mechanical properties of composites using a mixed matrix of 70% polyester resin and 30% vinylester resin with the hand lay-up method and impact testing based on the ASTM D6110 standard, several conclusions can be drawn as follows.

1. The addition of banana stem fiber significantly impacts the mechanical properties of the composite, particularly its impact strength. The greater the amount of banana stem fiber added to the matrix, the greater the composite's ability to absorb impact energy. This indicates that banana stem fiber acts as a reinforcing material, increasing the composite's toughness.
2. Test results showed that the fiber-free composite variation (0 grams) produced the lowest energy absorption and impact strength values compared to all variations using banana stem fiber. Conversely, the addition of fiber up to 12 grams resulted in the highest average energy absorption value, resulting in the composite having better impact resistance.
3. Based on impact strength calculations, the impact value increased with increasing banana stem fiber content. This indicates that the fibers help distribute the impact load from the matrix to the fibers, resulting in slower fracture compared to unreinforced composites.
4. Despite the improvement in mechanical properties, there was still variation in test results for each specimen of the same composition. These differences are thought to be due to the hand-layup manufacturing process, which allows voids (air bubbles) to form, the fiber distribution being less than uniform, and the less than homogeneous resin impregnation process.
5. Of all the variations tested, the composite with the addition of 12 grams of banana stem fiber in a matrix of 70% polyester and 30% vinylester mixture showed the best performance in impact testing. This

variation produced an average absorbed energy of 11.66 Joules with the highest impact strength value compared to other variations, so it can be declared the best composition in this study.

**Suggestion**

Based on the results of the research that has been conducted, there are several suggestions that can be given for the development of further research, namely as follows.

1. Further research is recommended to use molding methods such as vacuum bagging or compression molding so that the resin distribution is more even and the number of voids in the specimen can be minimized so that the test results are more consistent.
2. Banana stem fiber should be given chemical treatment, such as using NaOH solution, to increase the roughness of the fiber surface so that the bond between the fiber and the matrix becomes stronger and the mechanical properties of the composite can increase.
3. Further research can add variations in the composition of the mixture of polyester resin and vinylester resin so that the most optimal matrix composition can be identified in producing the mechanical properties of the composite.
4. Research is needed on variations in fiber orientation, fiber length, and more diverse fiber volume fractions to obtain the optimum composition and increase the potential for utilizing banana stem fiber as an environmentally friendly composite material.
5. The results of this study are expected to be a reference for further research in the development of natural fiber-based composite materials as an alternative material that is lightweight, economical, environmentally friendly, and has the potential to be applied in the automotive, light construction, and manufacturing industries.

**REFERENCE**

[1] F. Prihatna Suhada, A. Ainur Rosidah, and V. Ayu Setyowati, “The Influence of Fiber Orientation and Treatment Variation of Natural Fiber Reinforced Composites on Tensile Strength and Toughness.”

[2] E. Rosmawatiet al., “The Effect of Filler Volume Fraction Variation on Mechanical Properties of Banana Stem Fiber Reinforced Polyester Composites,” ***Nurul Huda University JIPFRI***, vol. 9, no. 1, pp. 16–23, doi: 10.30599/jipfri.v9i1.4170.

[3] K. Boimau, “The Effect of Fiber Orientation on Tensile Properties of Banana Fiber Reinforced Polyester Composites”, [Online]. Available: http://ejournal-fst-unc.com/index.php/LJTMU

[4] Ardhi Harist Hirosana, Sri Hastuti, and R. Faiz Listyanda, “The Effect of Weaving Angle on Banana Stem Fiber Reinforced Composites with Unsaturated Polyester Matrix,”Mars: ***Journal of Mechanical, Industrial, Electrical and Computer Engineering***, vol. 3, no. 2, pp. 69–75, Apr. 2025, doi: 10.61132/mars.v3i2.761.

[5] M. Madgule, P. Deshmukh, K. Perveen, MO Qamar, A. Razak, and AW Wodajo, "Experimental investigation on mechanical properties of novel polymer hybrid composite with reinforcement of banana fiber and sugarcane bagasse powder,"Advances in Mechanical Engineering, vol. 15, no. 10, Oct. 2023, doi: 10.1177/16878132231203810.

[6] Y. Gangurde, K. Deshmukh, S. Dhutre, D. Jangam, and SB Year, “A Comprehensive Review Article on Natural Fiber Polymer Composites.”

[7] S.-J. Park and M.-K. Seo, “Types of Composites,” Interface Science and Technology, vol. 18, pp. 501–629, Jan. 2011, doi: 10.1016/B978-0-12-375049-5.00007-4.

[8] J. Yao, Z. Zhou, and H. Zhou, “Polymer Matrix Composites,” pp. 113–137, Jan. 2019, doi: 10.1007/978-981-13-6068-8_5.

[9] H. Rozaki Yudha, Z. Abadi, and A. Arafat, “Analysis of Thermal Stability and Tensile Strength of Fiber Composites Using Unsaturated Polyester Resin Reinforced by Sugarcane Bagasse Fiber, Pineapple Leaf Fiber, and Banana Stem Fiber.”

[10] JH Kumar, S. Prabhakaran, KA Pandi, and KN Karthick, “Experimental Investigation on Mechanical Properties of Banana Fiber Reinforced Vinyl Ester Resin Composites,” pp. 1079–1093, Jan. 2021, doi: 10.1007/978-981-15-8319-3_107.