Electronic Journal of Education, Social Economics and Technology
Vol. 5, No. 1, (2024), pp. 1~9
ISSN 2723-6250 (online)
DOI: https://doi.org/10.33122/ejeset.v5i1.137

SAINTIS publishing

Research Article

Effect of Volume Fraction Variation of Hybrid Composite Reinforced Bamboo Fiber and Fiber-Glass Using Polyyester Resin on Tensile Strength and Impack

Akbar Gultom*, Ferri Safriwardy, Muhammad Nuzan Rizki, Masrullita

Department of Mechanical Engineering, Faculty of Engineering, Universitas Malikussaleh, Lhokseumawe, 24352, Indonesia
*Corresponding Author: ferri@unimal.ac.id

ABSTRACT

The field of materials and technology has developed rapidly, various types of inventions have been developed and researched to obtain new materials that are suitable for use at low production costs. The potential of bamboo plants is promising where the availability is abundant and sustainable, the utilization of specimens is made with polyester binders reinforced with natural and synthetic fibers. The type of bamboo that will be investigated for the tensile strength and toughness of the specimen with the difference in fiber volume fraction is a reference for the combination of bamboo fiber and fiber-glass where the volume fraction of 25% SB:25% FG, 35% SB:15% FG and 40% SB:10% FG particles at a fixed resin volume is 50%. Of the three variations in the volume fraction, the highest tensile strength in a balanced fiber filler is 40% bamboo fiber: 10% fiber-glass with an average value of 80.907 MPa, with a tensile strain of 2.53 % The lowest tensile strength value is in the volume fraction of 35% bamboo fiber: 15% fiber-glass with an average value of 75.552 MPa, with a tensile strain of 2.09%. For the highest toughness value of the specimen is in the volume fraction of 35% bamboo fiber: 15% fiber-glass, i.e., 0.83 J〖/mm〗^2 With an absorbed energy of 43.73 joules. On the other hand, the lowest toughness value is in the volume fraction of 25% bamboo fiber: 25% fiber-glass with an average value of 0.24 J〖/mm〗^2. With an absorbed energy of 39.94 joules. The observation results showed that the fiber volume was good at a percentage of 40% SB with 15% FG suitable for combination as an alternative tensile material. The toughness value in the volume fraction of 40% SB:10% FG is very low. However, the observation of bamboo fiber fracture results has a strong enough ability for the application of manufacturing products and others.

Keywords: bamboo fiber; volume fraction; polyester; tensile test; impact test; specimen fracture

1. INTRODUCTION

Technological developments have a great influence on the development of the field of materials engineering. Various types of materials continue to be developed and researched to get the right materials at low cost. Synthetic fibers are the main material in the application of manufactur products, etc. synthetic fibers are man-made fibers in the process of mixing chemicals at a relatively high cost, to balance synthetic fibers in their use, natural fiber composites are able to produce good strength and have advantages, environmentally friendly to their use. Hyibrid composite is a composite of two or more fibers which is a combination of fibers of different types and properties, the combination of several fibers can improve the mechanical properties of the composite material as desired. (Riyanto Adetya., 2018) conducted research on Hybrid composites are natural fibers and synthetic fibers (synthetic) in the form of coconut stem fibers and *glass fiber fibers.* The results of the study show that the highest bending strength of the hybrid composite of the two fibers with a volume fraction of 10:20% is 22.7 N/mm^2, then 15:15% and 20:10 is 19.6 N/mm^2 and 17.37 N/mm2 so that the composite is lightweight, corrosion resistant and cheaper.

Bamboo fiber has good potential to be developed into a strong, cheap and environmentally friendly composite material, in addition to having high potential, bamboo plants are very easy to get in tropical areas, especially bamboo that has *the bamboo genus*. This is based on a statistical survey by a scientist named *ucimura* (1980) which stated that 80% of the world's bamboo is in the region in South Asia and Southeast Asia and the bamboo genus bamboo is the most common type of bamboo found in the tropics. Bamboo plants are abundant plants in Indonesia, bamboo has fibers that can be used as a basic material for composite materials. Bamboo has a stem shape consisting of fibers The length and stem shape consisting of fibers and segments allow bamboo to stand upright and the specific gravity of bamboo ranges from 600 to 900 kg/m3. Meanwhile, the average weight of apus bamboo is around 820 km/m^3. (Porwanto and Johar., 2008).

Hybrid Composite Fiber jute fiber glass resin yukalac 157 and the catalyst that underwent coating, at the value of the second layer was 0.482 (KJ/m^2) and experienced an increase of 0.00142% in the third layer with an impact strength value of 0.624 (KJ/m^2), and in the fourth layer there was an increase of 0.0034% with an impact strength value of 0.964 (KJ/m^2).

Therefore, it can be concluded that the more layers of composite material, the greater the value (Mokar and Mukhlis., 2022). To obtain the equation of the volume fraction in the manufacture of test specimens consists of two, namely the volume of fibers and the volume of the weight of the composite. While the value of fiber density and matrix density $(pf)(mf)$ then, composites can be calculated by fractions in the fiber volume equation before printing, then it is done with the following equation:

$$\text{Wf} = \frac{vf}{wc} = \frac{vf\ vs}{pc\ vf} = \frac{vf}{vc}$$

Where: Wf= Fiber weight fraction, wf = Fiber Weight, wc = Composite weight, ρc = Density Serat, ρf = Composite density, Vf = Fiber Volume Fraction, Vm = Matrix Volume Fraction, vf = Fiber volume, vm = matrix volume. If the density of bamboo fiber and fiber-glass has been determined, then the calculation of the volume fraction is with the following equation:

$$\text{Vf} = \frac{mf/vf}{mf/vf + mm/vm}$$

This study aims to determine the value of the highest tensile strength and specimen toughness in the volume fraction of hybrid composite with fiber volume variations, namely 25% SB: 25% FG, 35% SB, 15% FG and 40% SB: 10% FG So the values obtained in the test are references that will continue, be it fiber use, product utilization and others.

The tests carried out are tensile testing and impact testing. Tensile testing is carried out to find stress and *strain values* while impact testing is carried out to find the strength and energy values absorbed by the specimen. Tensile strength and elongation (*elogation*) are formulated by the tensile test formula:

Tensile streght (σ)

$$\sigma = \frac{F}{A}$$

Where, σ = Tensile strength (MPa), F = load given perpendicular direction (N/m^2), A = The cross-sectional area of the specimen before loading (mm).

$$\varepsilon = \frac{Li - Lo}{L0} = \frac{L\Delta}{L0}$$

Where: ε = Elongation Lo = The starting length of the specimen before it is subjected to loading, dan $L\Delta$ = Length increase after testing.

$$\in = \frac{\sigma}{\varepsilon}$$

Where: $\in$ = Modulus of elasticity (MPa), σ = tensile strength (MPa) dan ε = Stretching (%)

Figure 1. Tensile testing tool

To find the absorbed energy and impact strength by using the following formula:
Ei = w.g.R (cos ß – cos α)

With: Ei = Energy *(joule),* W = Pendulum weight (kg), g = Gravitasi (m/s2) R = Swing length (mm), α = The initial angle of the pendulum ß = pendulum end angle

The impact price can be calculated with the formula: $HI = E \times A0$

HI = Impact pricing (joule), E= Energy to break materials, Ao = The smallest cross-sectional area of the notch (cm²), Es = Energy absorption (J). Here is a picture of the charpy impact testing tool on the standard ASTM D110-10

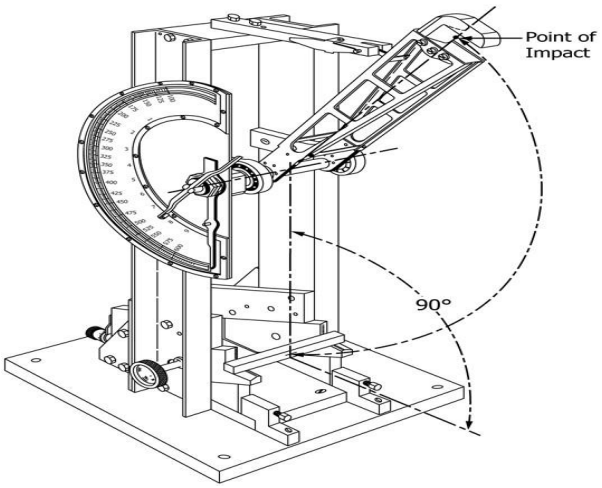

Figure 2. Impact testing tool

2. RESEARCH METHOD

Test Specimen Preparation

Composite is a combination of materials consisting of two or more different materials and has the advantage of each by fusing to form a new material bycombining the two fibers on the mold and then the volume calculation is carried out.

Research Variables

Independent Variable
The variables are fiber volume 25% SB: 25% FG, 35% SB: 15% FG and 30% SB: 10% FG

Fixed Variables
The fixed variables in this study were resin and catalyst volume (50%), elongated random laminate arrangement, hand lay up.

True Experimental Reserch

The experimental method is a method that aims to test the influence of another variable or test how the causal relationship between independent variables to fixed variables., the calculation of the volume fraction into Steps on the research variable, The following is:

Table 1. Specimen volume calculation

Volume Specimens	Faction Volume	Volume	Resin	Volume
$10{,}72cm^3$	25% SB	$26{,}81cm^3$	50 %	$53{,}62cm^3$
	25% FG	$26{,}81cm^3$	50%	$53{,}62cm^3$
$10{,}72cm^3$	35% SB	$37{,}53cm^3$	50%	$53{,}62cm^3$
	15% FG	$16{,}08cm^3$	50%	$53{,}62cm^3$
$10{,}72cm^3$	40% SB	$42{,}90cm^3$	50%	$53{,}62cm^3$
	10% FG	$10{,}25cm^3$	50%	$53{,}62cm^3$

Table 1 is the results of the calculation of the volume fraction used in the manufacture of tensile test specimens where the volume of one specimen is 10.72 cm^3

Research Procedure Flowchart

The stages of the research flow carried out in the implementation of the tensile and impact tests are attached in the following flow diagram.

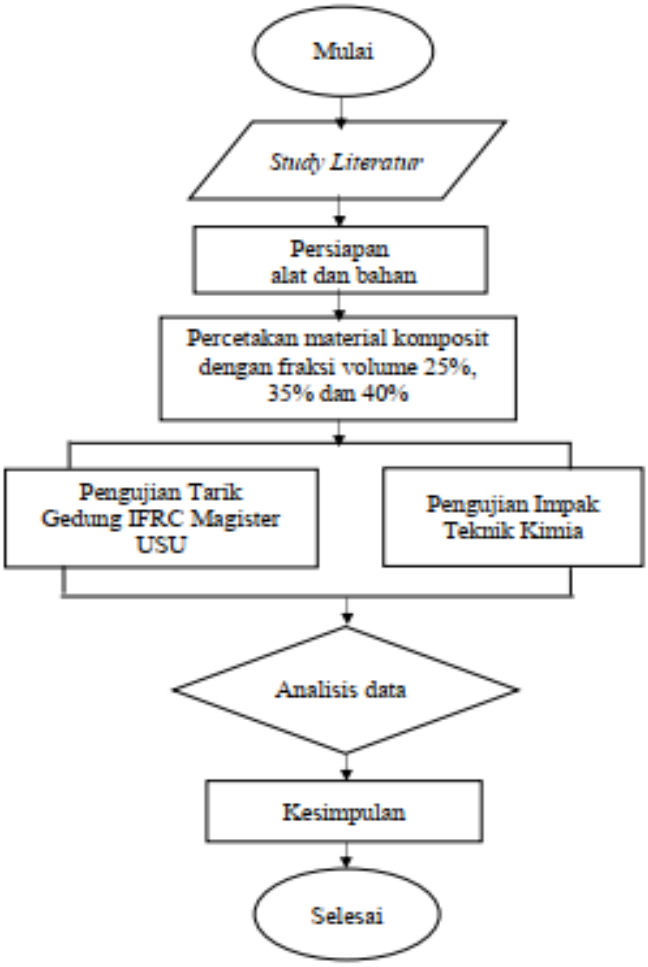

Figure 3. Research flowchart

The research test material is a specimen, in accordance with tensile testing standards ASTM D638 -14 and Charpy Impact testing ASTM D6110-10.

3. RESULTS AND DISCUSSION

After testing the specimen, data was obtained in the form of tables and graphs. The analysis of the data regarding the percentage variation of the fraction volume 25 SB %: 25% FG, 35 SB% :15% FG, 40% SB:10% FG aims to determine the magnitude of the tensile strength and impact of the tensile test specimen and the impact on bamboo fibers and fiber-glass with BQTN 157 EX polyyester resin. The tensile test is carried out after the stage of specimen making according to the ASTM D638-14 Standard totaling 15 test specimens in each variation of the volume fraction there are 5 specimens, the following Table 2 is the average value in the tensile test.

Table 2. Average value of tensile test

Variations Volume fraction	Cross-sectional area mm^2	Tensile strenght	Modulus young
		MPa	Mpa
25% SB 25% FG	65	76.340	34.12
35% SB 15% FG	65	75.552	36.01
40% SB 10% FG	65	80.907	31.96

In table 2 which shows the average value of the tensile test, there are 5 test specimens in each volume fraction so that an accurate average value is obtained on the volume fraction of 25% SB: 25% FG of the cross-sectional area 65 mm2 with a

tensile strength of 76.340 MPa for an elastic modulus value of 34.12 MPa. For the volume fraction of 35% SB:15% FG, the cross-sectional area is 65 with a tensile strength of 75.552 while the modulus of elasticity value is 36.01 MPa. And a volume fraction of 40% SB:10% FG with a cross-sectional area of 65 specimens with a tensile strength of 80.907 MPa for an elastic modulus value of 31.96 MP mm²

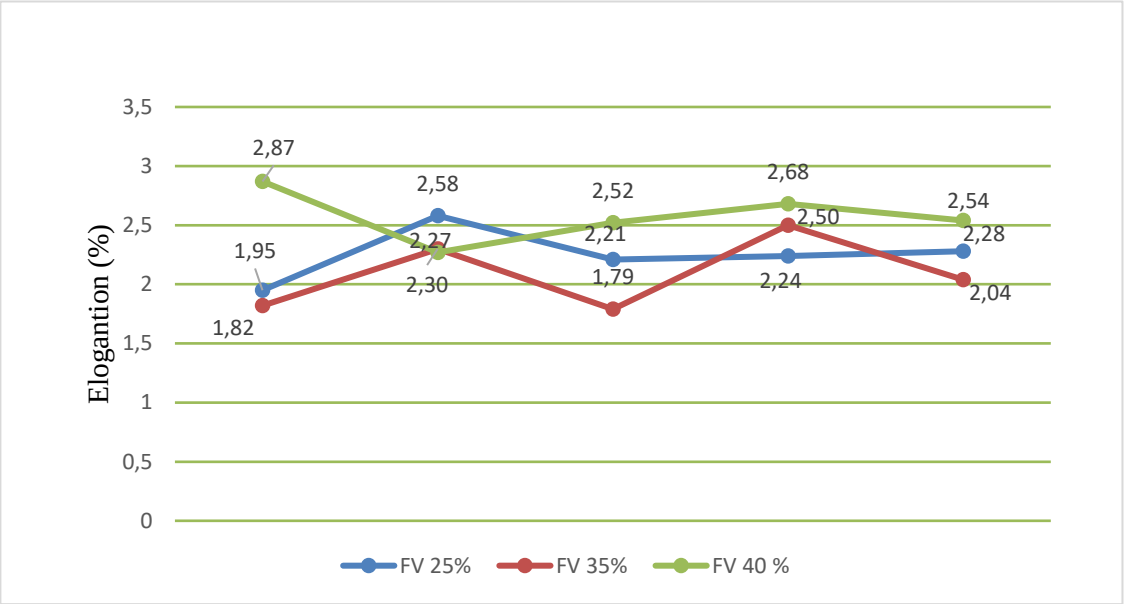

Figure 4. Graph of tensile test specimen elongation value

In **Figure 4**, the graph compares the results of specimen strain between Fv25% SB, 35% FG and 40% SB: 10% FG For the lowest strain value at Fv 35% is in specimen 3 which is 1.79% while the highest strain is in specimen 4 which is 2.50%. For the lowest 25% of the strain value is in specimen 1, that is, 1.95% in the highest strain is found in specimen 2, which is 2.58%. In the volume fraction of 40% FG, the lowest strain yield value is in specimen 3, which is 2.27%, in the highest strain, it is in specimen 4, which is, 2.68%

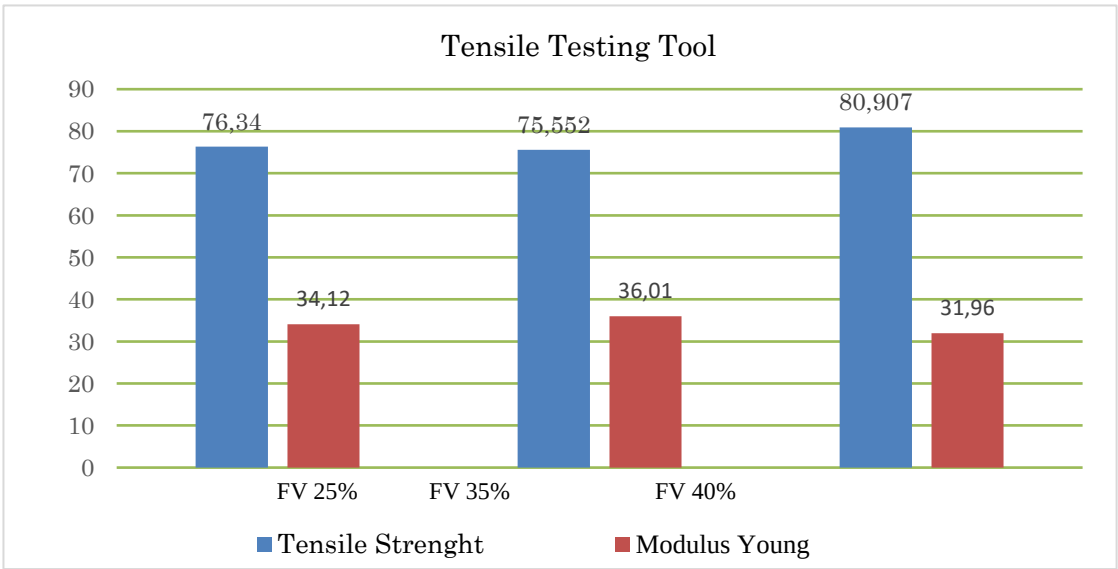

Figure 5. Tensile test average value diagram

Based on the data of the average results of the tensile test in the diagram above from the variation of the highest volume fraction, which is 40% SB:10% FG with a tensile strength value of 80.907 MPa, on the other hand, the lowest volume fraction is at 35% SB:15% FG with a tensile strength of 75.552 MPa.

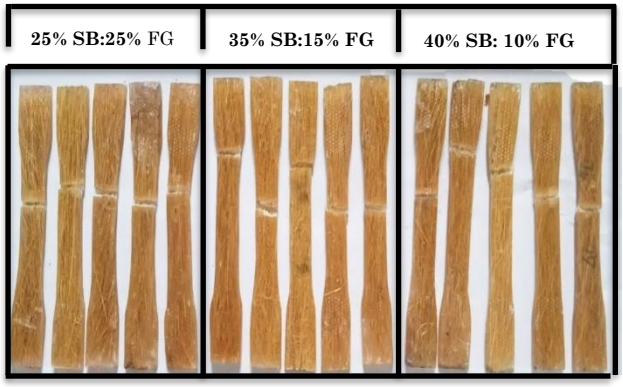

Figure 6. Specimen of Tensile Test Results based on Fv

In **Figure 6** we can see that the specimen elongation values of the volume fraction variation are different based on the volume fraction results. In the volume fraction of 25% SB:25% FG has an average extension value of 2.25%. For the volume fraction of 35% SB: 15% FG 2.04%, and the volume fraction of 40% SB: 10% FG has an average value of 2.53%. The following is a picture of the tensile test results of the specimen on the volume fraction shown in Figure 7 The following will show the specimen from the impact test fracture based on the volume fraction.

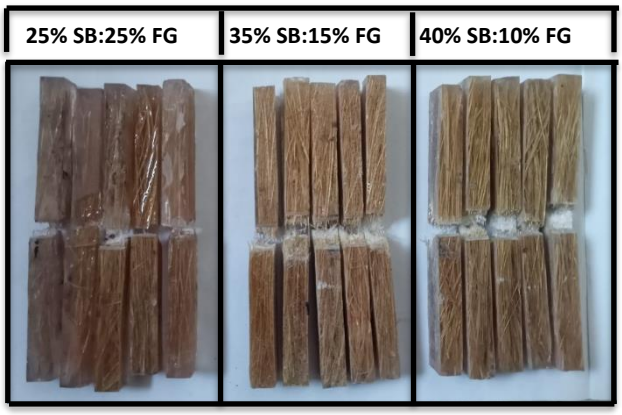

Figure 7. Impact test results based on volume fraction

Table 3. Average impact test values

Faction Volume	Cross-sectional area mm²	Beginning angle (α)	End angle (β)	Energy absorb (joule)	Strength Impact (J/mm²)
25%:25%	127	160	135	30,94	0,24
35%:15%	127	160	96,4	46,73	0,83
40%:10%	127	160	98,8	64,16	0,79

In **Table 3**, the average value of the impact test with a cross-sectional area of the specimen is 125 fractions of 25% SB:25% FG with an average value of 30.94 J of absorbed energy while the impact force is 0.24 J / .fraction of 35% SB:15% FG with an average value of 46.73 J of absorbed energy while the impact strength is 0.83 J/mm^2mm^{2}mm^2. volume fraction 40% SB:10% FG with an average value of absorbed energy of 98.8 J while the impact strength is 0.79 J/mm^2.

In **Figure 8** the graph of absorbed energy based on volume fraction for five test specimens has different values. For 25% SB: 25% FG, it has the lowest absorption energy values in specimens 4 and 5 with values of 21.11 and 22.93 joules, For the volume fraction of 35% SB: 15% FG has the lowest values in specimens 4 and 5 with values of 10.11 and 21.11 joules. And the volume fraction of 40% SB:10% FG of the lowest specimen was at numbers 4 and 5 with values of 10.2 and 11.1 joules. Here Figure 9 will display a graph of impact strength values.

The data obtained from the absorbed strength of the impact test specimen is related to the toughness of the impact value. In Figure 12 the strength value of the specimen is at the volume fraction of 35% SB: 15% FG is at specimen number 4 with a value of 0.87 (J/mm^2). For the volume fraction of 40% SB: 10% FG the highest specimen is at specimen number 4 0.87 J/mm^2). And the volume fraction of 25% SB:25% FG of the highest specimen is in specimens number 1 and 2 with a value of 0.31 J/mm^2). Here is Figure 13 Average value of impact strength based on volume fraction.

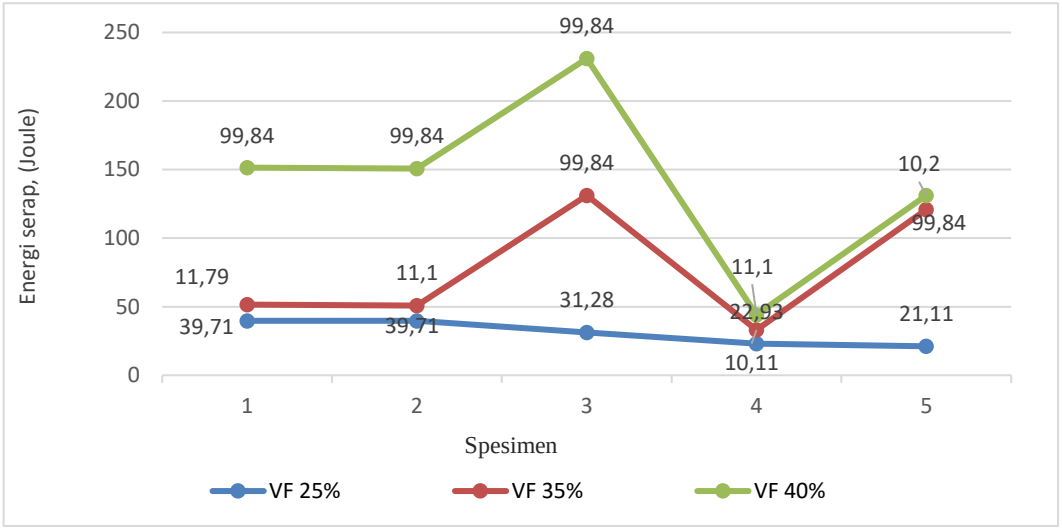

Figure 8. Value of absorbed energy volume fraction

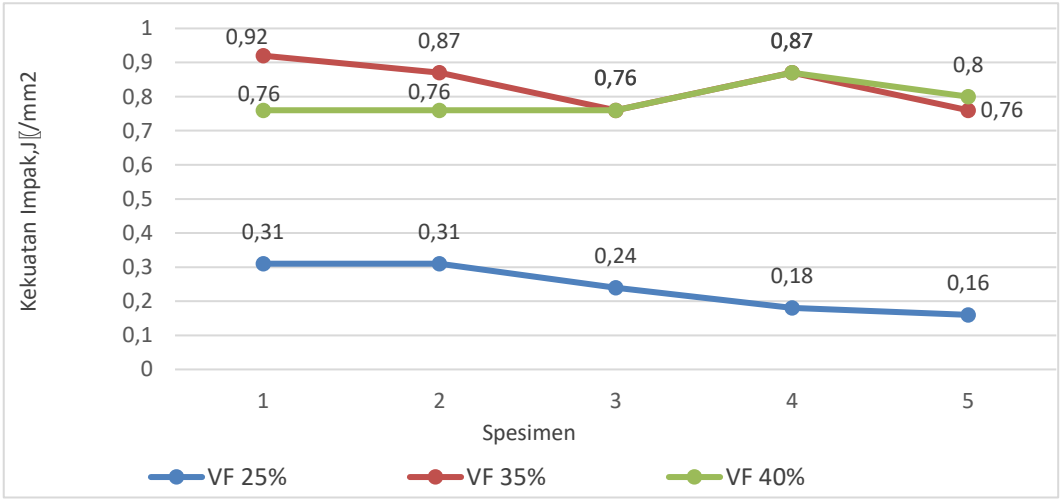

Figure 9. Strength value Impact fraction volume

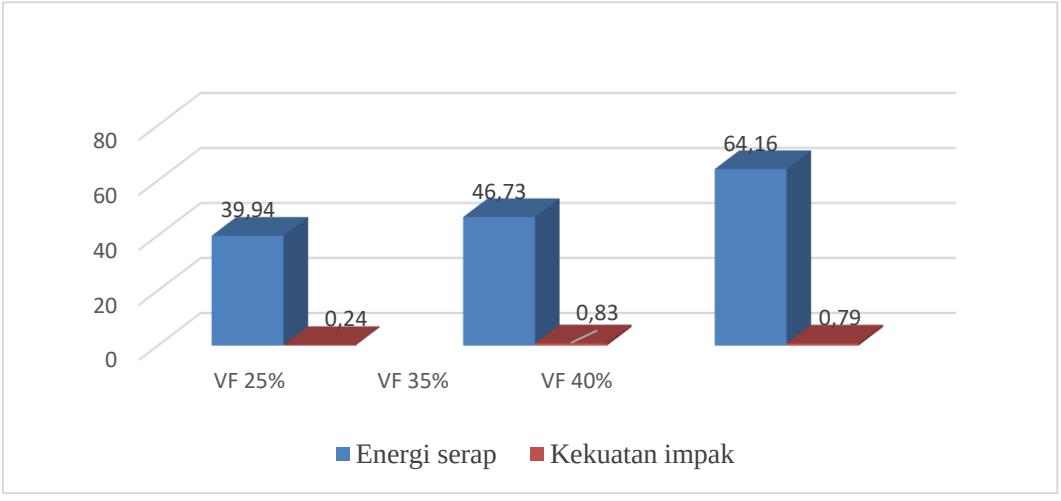

Figure 10. Average value of impact strength

The data obtained from the results of impact tests on hybrid composites on both bamboo fibers and *fiber-glass* shown in the figure of 10 fractions of volume 25% SB:25% FG obtained the lowest absorption energy value of 39.94 Joules with an impact strength of 0.24 J/mm². for the volume fraction of 35% SB:15% FG obtained an absorption energy value of 46.73 Joules with the highest impact strength with a value of 0.83 J/mm². while the volume fraction of 40% SB:10% FG obtained an absorption energy value of 64.16 Joules with a higher impact strength than the volume fraction of 25% SB:25% FG with a value of 0.79 J/mm².

Specimen fracture observations were made on each volume fraction. The following are the fracture results of impact testing specimens.

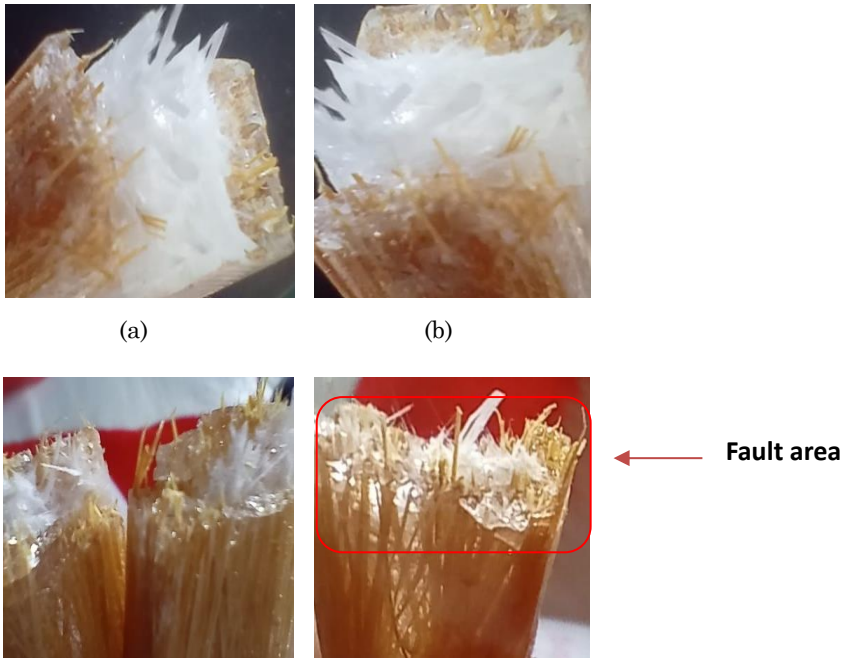

Figure 11. Fracture Of An Impact Test Specimen

In **Figure 11**, the specimen fracture photo shows the formation of fractures in several specimens by dominating hard but brittle fractures that result in *fiber pull-out* visible in the fiber fractures that come out because the bonds between the fibers and the matrix are not strong, the fractures are also caused by voids around the fibers. In the fracture of figure (a) there is *a fiber pull out* while in figure (b) there is a void and in figure (c) there is *a fiber pull out,* for fibers that undergo *pull out*, the fiber bond with the matrix is not fully attached, as a result of *debonding* occurs in the fracture of the test specimen. (Textbook on the theory and application of composite and polymer materials.

4. CONCLUSION

The volume of tensile and impact test specimens greatly affects the test results, resulting in different values on each volume fraction. The highest tensile strength values were found in the volume fraction of 40% SB:10% FG with average values of σ=80.905 MPa, ε = 2.53%, and ∈ = 31.96 MPa. In the Charpy impact test, the highest volume fraction was at 35% SB:15% FG with an impact strength of E = 0.83 joules and 46.73 J/mm². The volume fraction of 25% SB:25% FG bamboo fiber has a higher tensile strength than the volume fraction of 35% with a value of σ = 76.340 MPa, but in the impact test it produces the lowest strength with HI = 0.24 J/mm² and E = 39.94 joules. The volume fraction of 35% SB:15% FG in the tensile test results in σ = 75.544 MPa and the highest elastic modulus value ∈ = 36.01 MPa, with an impact strength value of HI = 0.83 J/mm² and an absorbed energy of 46.73 joules. In the highest tensile test, the volume fraction of 40% SB:10% FG was obtained with σ = 80.905 MPa, but the elastic modulus value dropped to ∈ = 31.96 MPa. The highest impact strength value was in the 40% fraction with HI = 0.79 J/mm² and E = 64.16 joules. The results show that the variation of the volume fraction in the specimen greatly affects the tensile strength value. The greater the elastic modulus value of a specimen, the greater the tensile strength obtained. This is because specimens with a higher elastic modulus will be stiffer and resistant to deformation, so the material can withstand higher stresses before the test specimen breaks.

AUTHOR'S CONTRIBUTIONS

All authors discussed the results and contributed to from the start to final manuscript.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

REFERENCES

American Society for Testing and Materials. (2016). ASTM D638-14, *Standard*. ASTM *International*, *82*(C), 1–15. https://doi.org/10.1520/D0638-14.1.

ASTM *International*. (2010). Astm D6110-10. *ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States*, *April*.https://doi.org/10.1520/D6110-10.1

Dicky, R. F. (2004). *Pengaruh JKonsentrasi Koh Terhadap Kekuatan Tarik Dan Struktur Mikro Komposit Serat Rami Dan Serat Bambu*. *1*, 1–14.

Fabiana Meijon Fadul.(2019). *Pengertian Komposit*. 5–33.

Hendrikus, W., Boimau, K., dan Maliwenu, E. (2015). Pengaruh Variasi Fraksi Volume Serat terhadap Kekuatan Bending dan Impak Komposit Polyester Berpenguat Serat Agave Cantula atau lebih gabungan konstituen yang dan tidak larut dalam satu sama lain . Salah. *Lontar Jurnal Teknik Mesin*, *02*(01), 39–50.

Lumintang, R. C. A., Soenoko, R., dan Wahyudi, S. (2011). *Komposit Hibrid Polyester Berpenguat Serbuk Batang dan Serat Sabut Kelapa*. *2*(2), 145–153

Mokar, A. S., dan Mukhlis, M. (2022). Analisis Pengaruh Komposisi Lapisan/Laminat Terhadap Kekutan Impak pada Komposit Hybrid Serat Jute, Glass dan Resin Yukalac 157 Katalis. *Dinamika*, *6*, 39 43.http://ejournal.unkhair.ac.id/index.php/Dinamik/article/view/4103%0Ahttp://ejournal.unkhair.ac.id/index.php/Dinamik/article/view/4103/2643

Rochim, T., (2001), "Spesifikasi, Metrologi, dan Kontrol Kualitas Geometrik", Institut Teknologi Bandung.

Porwanto, D. A., dan Johar, L. (2008).Karakterisasi komposit berpenguat serat bambu dan serat gelas sebagai alternatif bahan baku industri. *Jurnal Teknik Fisika ITS*, 1–16.

Putra, F. U., Paundra, F., Muhyi, A., Hakim, F., Triawan, L., dan Aziz, A. (2023). Pengaruh Variasi Tekanan Dan Fraksi Volume Pada Hybrid Composite Serat Sabut Kelapa Dan Serat Bambu Bermatriks Resin Polyester Terhadap Kekuatan Tarik Dan Bending. *Journal Foundry*, *6*(1), 8–15.

Prasansi Harmi dan Tjahjanti., (2018). Buku Ajar Teori Dan Aplikasi Material Komposit Dan Polimer. *Umsida Press*, 1-24.

Riyanto Adetya., 2018. (2018). Pengaruh fraksi volume serat komposit *hybrid* berpenguat serat bambu acak dan serat e-glass anyam dengan resin *polyester* terhadap kekuatan bending. *Jurnal Teknik Mesin*, *06*(02), 55–60.

Zulmiardi, Meritna, A. (2019). Pengaruh fraksi volume terhadap kekuatan tarik komposit polyester BQTN type 157-Ex yang diperkuat serat abaka. *Seminar Nasional Teknik Industri*, *4*(1). https://repository.unimal.ac.id/4989/1/30-Paper-SNTI-2019.pdf