JIT Journal of Innovation and Technology
e-ISSN: 2721-8562; p-ISSN: 2721-8570
Vol. 6, No. 2, October 2025. Page: 54 – 59

The Effect of Fracture Strength of Composite Materials with the Addition of Pineapple Leaf Fiber

Nusyirwan Nusyirwan [1,*], Rispandi [1] , Alfikri Ikhsan [1]

[1] *Department of Mechanical Engineering, Faculty of Engineering, Universitas Andalas, Kampus Limau Manis, Padang 25163, Indonesia*

*Corresponding Author: nusyirwan1802@gmail.com

Article history
Received: 07.08.2025
Revised: 16.09.2025
Accepted: 21.10.2025

DOI:10.31629/jit.v6i2.7544

Abstract
Composite materials with unsaturated polyester matrix reinforced with natural fibres were developed to make biodegradable composite materials so that the waste does not damage the environment. Regarding mechanical strength, natural fibre-based composites are still lower in mechanical strength than composite materials with synthetic fibre reinforcement. These weaknesses include easy cracking when hit because they are brittle and have a small plastic deformation area. Some actions that will be carried out in this study are the addition of pineapple fibres with unsaturated polyesters that can form composites that are resistant to cracking. The addition of pineapple fibers to unsaturated polyesters up to 20% can have the highest fracture strength with a value of K_{1C} = 1.733 MPa.m$^{0.5}$, whereas pure unsaturated polyester without a mixture of pineapple fibres only has a fracture strength of K_{1C} = 0.779 MPa.m$^{0.5}$. From the results of the study, the addition of pineapple fibres can increase the fracture strength of polyester materials by 222.47%.

Keywords: Reinforcement, cracking, fracture,strength

1. Introduction

Currently, composite materials are widely used in transportation systems and other engineering fields to reduce the use of heavy and easily corrosive metal materials[1-3]. The composite material is derived from lighter polymer materials, which are cheaper to form and can be reinforced with natural fibres to obtain good mechanical strength.[3-5]. The function of the main polymer material combined with reinforcing materials from natural fibers to create superior composite materials has been widely applied in the structural field. Efforts to increase the advantages of polymer composite materials are to increase their mechanical strength using various methods so that their use is widespread[2][4][5]. But besides that, polymers have several weaknesses, including having low tensile strength, being brittle and cracking easily, and not being able to withstand high temperatures[6][7][4]. The main problem of polymers is their low mechanical strength and heat resistance, so they must be reinforced with synthetic fibres or natural fibers such as hemp and other fibres [8]. Previous researchers have attempted to process polymers so that their mechanical strength can be increased and they can operate at high temperature ranges without fatigue[9][10]. Previous research can increase the strength of polymer composites with hemp fiber

DOI: DOI:10.31629/jit.v6i2.7544

and other fibres[11]. Furthermore, the reinforcement of composites with bagasse fiber has been reported by[12].

The important subject of this research is using unsaturated polyester for the composite matrix and its reinforcement with pineapple leaf fiber and its mechanical strength against cracking is evaluated. This study refers to previous research using pineapple leaf fiber to make a composite material with a brittle pine resin matrix, and obtained a tensile strength of 2.4 MPa[13-14]. From the results of previous research, no one has reported a study on the strength of pineapple fibre composites with a matrix of unsaturated polyester (UP). This is the research that will be carried out here regarding the ASTM D5405 crack test standard[15-16][3].

2. Materials and Methods

2.1 Materials for Research

In this study, the strength of the material to withstand the crack load acting on it will be evaluated by creating an initial crack at the crack tip and the load is pulled vertically with an opposing force. From the results of the load pulling, cracks will form, and the material will resist and form concentrated stress to become the critical stress intensity of the material with a price known as the critical stress intensity factor (K_{1C}). The type of polymer used to make the composite matrix is unsaturated polyether brand Yukalac 1560 BL-EX with properties that can bind fibers well and has good dimensional stability.

The process of selecting good pineapple fibre with binding lignin is done by rolling, combing, and drying it in the sun, cleaning it, drying the fiber eq. and drying it in the sun, then selecting good fibre as the process of selecting good fibre can be seen in Figure 1.

(a). **(b).** **(c).** **(d).**

Figure 1. Pineapple fibre processing process.

In Figure 1, the pineapple fiber processing process can be explained, namely the separation of pineapple fiber from lignin a). Pineapple leaf morphology, b). Sorting separation of pineapple leaf fiber, c). Sun drying for pineapple fiber, d). Dried pineapple fiber.

2.2 Composite Material Manufacturing

The composite material is first made by manually weaving pineapple leaves with a width according to the width of the crack test specimen, then pouring resin into a mold filled with fiber repeatedly and pressing it with a flat glass plate while smoothing it with a roller or brush until it reaches the desired thickness. and dried in the open air (room temperature) for 48 hours. This research refers to previous regulations[17][18]. The pineapple fibre, a single type of woven fibre mixed with polyester, is evenly distributed. The manufacturing process involves pouring the evenly distributed mixture into a mold and then pressing it evenly with a roller or brush. This process is repeated until the standard thickness is achieved. The composite material manufacturing process can be seen in Figure 2.

Figure 2. Unsaturated polyester in packaging bottles.

The composition of the mixture of materials to be made into composite materials has been designed with a composition that is hypothesized to produce crack-resistant materials as in Table 1 below;

Table 1. Mixed composition of Polyester (UP) and Pineapple Fiber (SN).

Material Number	Polyester Composition (% Volume)	Pineapple Fiber Composition (% Volume)
1	100	0
2	90	10
3	80	20
4	70	30

3. Crack Testing Process.

To conduct composite material crack testing, a cracking machine is used with vertical tensile force on both sides moving vertically, in opposite directions according to the reference standard, namely ASTM D5405, the dimensions of which

DOI: DOI:10.31629/jit.v6i2.7544

can be seen in Figure 5. This tool will be able to work by inputting the material specification data needed to calculate the cracking strength of the test material specimen.

3.1 Standard Dimensions of Test Materials

To make composite materials, a mold is required that can make materials with appropriate dimensions that refer to the ASTM D5405 standard dimensions which can be seen in Figure 3.

The dimensions of the test object are in accordance with ASTM D 5405 standards, with a material width of 200 mm, a material thickness of 12 mm, a crack area length of w = (53 – 18) = 35 mm and an initial crack, a = 18 mm.

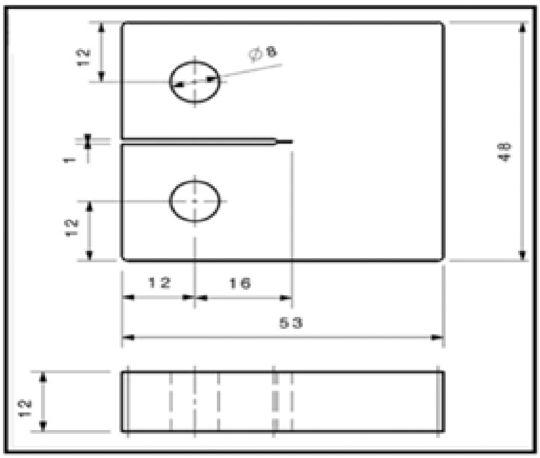

Figure 3. The dimensions of the test object refer to the ASTM D5405 standard.

3.2 Equations of Fracture Strength

The mathematical equation used to calculate the fracture strength of a material is as follows

$$K_{Ic} = \frac{P}{BW^{1/2}} \cdot f\left(\frac{a}{w}\right) \qquad (1)$$

Next, the crack propagation function f(a/w) can be described by the following equation

$$f\left(\frac{a}{w}\right) = \frac{\left(2+\frac{a}{w}\right)\left\{0.886+4.64\left(\frac{a}{w}\right)-13.32\left(\frac{a}{w}\right)^2+14.72\left(\frac{a}{w}\right)^3-5.6\left(\frac{a}{w}\right)^4\right\}}{\left(1-\frac{a}{w}\right)^{3/2}} \qquad (2)$$

Where:

K_{1C} is the fracture toughness value of the material, with units of $MPa \cdot m^{2}$
P is the internal crack load in N
B is the width of the material in mm
W is the length of the crack area in mm

The Crack Testing Machine functions to carry out crack tests by carrying out vertical movements in two opposing directions to pull the crack test material. It can move as the load increases automatically if the material resists. To conduct a crack test of composite materials, a crack test is used for the composite sample crack test that has been made, according to the referenced standard, namely ASTM D 5405, the dimensions can be seen in Figure 2. In this tool, the material specification data required for the analysis of the crack strength properties of composite material samples can be input. The specifications of the crack test machine are as follows; COM-TEN testing machine brand 95T Series 5K, Capacity 5000 Pounds, Load Cell Model TSB0050, with a touch screen display monitor or com-touch screen. The crack test machine can be seen in Figure 3.

Figure 4. The Crack testing machine with COM-TEN Brand 95T Series 5K.

4. Results and Discussion

From the results of crack testing on each composite material test specimens can be displayed directly automatically on the monitor of the crack testing machine. The test results show that the maximum cracking load price on each material test sample can be seen in Table 2 below. The cracking load price for each crack test specimen can be seen in Table 2. From the table above, it is shown for the test specimens of each UP and SN material mixture and from the test shows that in pure UP, it ranges from 0.598 kN. When pineapple leaf fiber is added starting from 10% in the UP material, the cracking force price increases to 1.1337 N. In the SN mixture in UP it is increased to 20%, the cracking force increases to around 1.606 kN. Furthermore, if the SN mixture in UP is increased to 30%, the cracking force decreases to 1.484 kN.

DOI: DOI:10.31629/jit.v6i2.7544

Table 2. Test Results of Crack Test Specimens of Composite (UP) and Pineapple Fiber (SN).

Material Composition UP/SN (wt% /wt%)	Cracking Force (kN)	Stress Intensity factor (MPa.m $^{0.5}$)
100/0	0.598 ± 0.032	0.779 ± 0.015
90/10	1.337 ± 0.075	1.207 ± 0.026
80/20	1.606 ± 0.578	1.733 ± 0.115
70/30	1.484 ± 0.026	1.337 ± 0.024

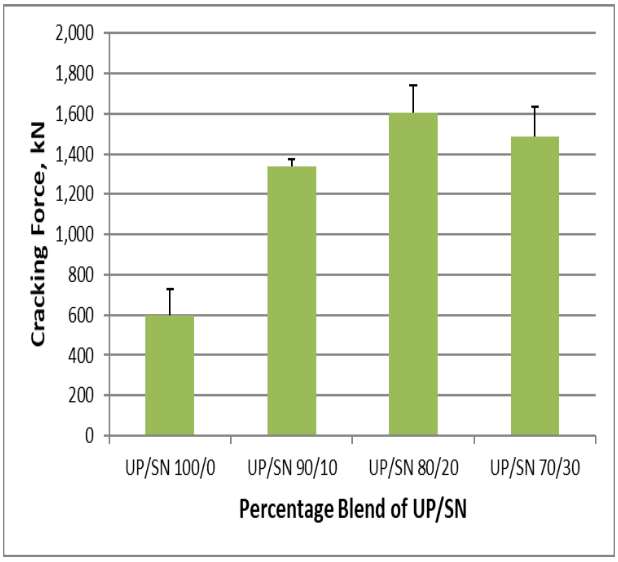

Figure 5. The Curve of Cracking Force of Composite (UP) and Pineapple Fiber (SN).

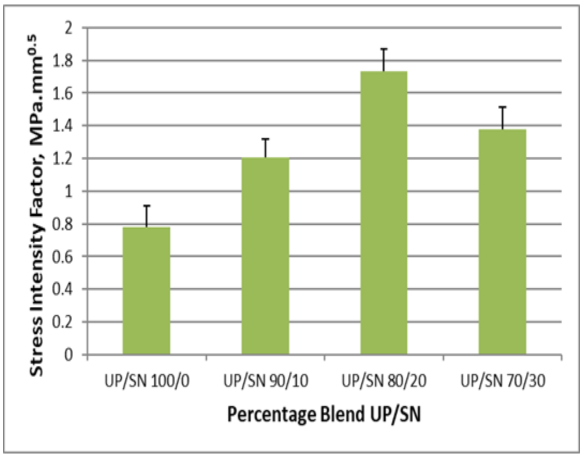

Figure 6. The Curve of Stress Intensity Factor of Composite (UP) and Pineapple Fiber (SN).

The results of the cracking force are in Table 2 shown in Figure 5. The cracking load value for each cracking test specimen can be seen in Table 2. From the table above, it is shown for the test specimens of each mixture of UP and SN materials and from the test it shows that in pure UP it is around 0.598 kN. When pineapple leaf fiber is added starting from 10% in the UP material, the cracking force value increases to 1.1337 kN. The maximum cracking force occurs in the SN mixture in UP is increased to 20%, the cracking force increases to around 1.606 kN. In the mixture of SN and UP exceeding 20%, saturation has occurred after the SN mixture of 30% the magnitude of the cracking force decreases.

This means that this mixture shows that not all pineapple leaf fibres are well bound to unsaturated polyester (UP) this as indicated by the material strength starting to decrease.

Next, the determining factor for the cracking strength of a composite material will be calculated by determining the value of the stress intensity factor (factor) using equations (1) and (2) for the test specimens of each UP and SN material mixture and is shown in Table 2. The results of the test show that in pure UP, the critical stress intensity factor is obtained at 0.779 MPa.m $^{0.5}$. If the mixture of unsaturated polyester and pineapple leaf fiber is added starting from 10% to the UP material, the value of K_{1C} of the critical stress intensity factor increases to 1.207 MPa.m$^{0.5}$.

Then, the addition of the SN mixture to the UP by 20%, the maximum critical stress intensity factor value is obtained at K_{1C} = 1.733 MPa.m$^{0.5}$. Furthermore, with the addition of pineapple fiber content to 30%, the critical stress intensity factor value is obtained, which decreases at K_{1C} = 1.337 MPa.m$^{0.5}$, these results can also be seen in Figure 7 (a). Furthermore, when pineapple fibre is added to polyester, there will be crack growth that begins to become rough (shown by the red arrow), because some adjacent polyester atom chains will begin to be blocked by pineapple fibres that begin to bind polyester molecules in the weakest molecular bond structure. This can be seen in areas that show different roughness of the crack surface, which indicates a difference in the percentage of pineapple fiber content bound to the ends of the polyester molecular chain. When the pineapple fiber content of 20% is mixed with polyester, the rougher crack surface begins to appear striped. This is because many ends of the polyester molecular chain are bound to the pineapple fiber and the level of roughness of the crack surface due to loading begins to resist the movement of the load, meaning that plastic deformation has begun to occur or the level of brittleness of the polyester has begun to decrease as shown in Figure 7(b). The level of toughness of the combination of polyester material with pineapple fibre increases along with the high pineapple fibre content of 20% combined with 80% polyester polymer. This indicates that the maximum level of crack strength rupture occurs on the crack surface, which shows the highest toughness. Figure 7(c). hen the percentage of pineapple fibre material was added up to 30%, the roughness level began to decrease, and the amount of pineapple fibre may have exceeded the saturation limit that can be bound to polyester molecules, in Graph 7(d).

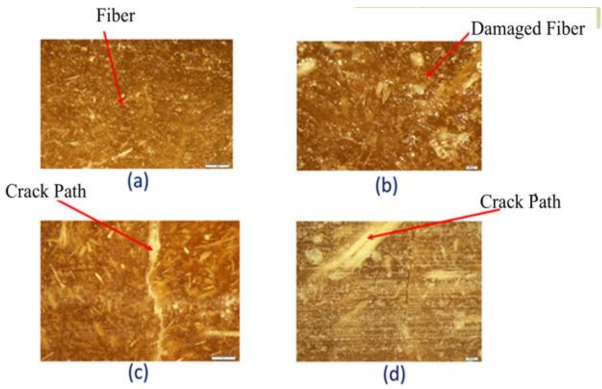

Figure 7. The Curve of Stress Intensity Factor of Composite (UP) and Pineapple Fiber (SN).

5. Conclusion

From several studies that have been conducted, it will be reported the success of determining the right composition of a composite material mixture made of an unsaturated polyester matrix with the addition of pineapple leaf fibre to increase the crack resistance of unsaturated polyester polymers into crack-resistant composite materials. With this research, in the engineering field, such as in the field of raw materials for fishing boat bodies, tourist boat bodies, and fishing boats, is very helpful. This unsaturated polyester mixture with 20% pineapple leaf fibre has the highest critical stress intensity factor of K_{1C} = 1.733 MPa.m $^{0/5}$, increasing from 0.779 MPa.m$^{0/5}$ in pure unsaturated polyester. With the highest performance, this material is able to withstand good crack strength, so it is good and useful for engineering applications. This research increased the toughness and crack resistance of the UP material treated with the addition of the SN mixture by 222.47%.

Acknowledgement

This research was funded by a research grant from the Faculty of Engineering with Research Contract No. 723.!6.09.D/FT/2023

[1] Nusyirwan, H. Abral, M. Hakim, dan R. Vadia, “The potential of rising husk fiber/native sago starch reinforced biocomposite to automotive component,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 602, no. 1, 2019, doi: 10.1088/1757-899X/602/1/012085.

[2] N. Nusyirwan, P. Abiema, dan A. Malik, “Methods Increased Fracture Toughness Thermosetting Polyester Mixture with Vi- nyl Ester for Raw Materials in Ship Bodies,” vol. 1, no. 1, hal. 43–50, 2023.

[3] Nusyirwan, F. Yande, H. Abral, Ihamdi, H. Dahlan, dan E. Satria, “Effect of variations in load speed on fracture toughness of thermoset polyester/thermoset vinyl ester blend,” *AIP Conf. Proc.*, vol. 2592, no. March 1996, 2023, doi: 10.1063/5.0115043.

[4] N. Nusyirwan dan R. Pratama, “Study on Increasing the Cracking Resistance of Unsaturated Polyester,” vol. 7, no. 2, hal. 84–89, 2023.

[5] M. . Nusyirwan.N, Hizhar.Y, “Study of Improved Crack Toughness of Unsaturated Polymers with Rice Husk Fiber and Sago Flour as Strengthening Materials,” *Polimesin*, vol. 21, no. 5, hal. 27–32, 2023.

[6] N. Adnan, H. Abral, D. H, dan E. Staria, “Identification of Mechanical Strength for Mixture of Thermoset Polyester with Thermoset Vinyl Ester due to Bending Load,” *JMPM (Jurnal Mater. dan Proses Manufaktur)*, vol. 6, no. 1, hal. 19–25, 2022, doi: 10.18196/jmpm.v6i1.14450.

[7] N. Nusyirwan, M. Rani, dan R. Pratama, “Identification of the fracture surface of thermoset polyester due to bending load,” vol. 7, no. 1, hal. 51–58, 2022, doi: 10.22219/jemmme.v7i1.23086.

[8] N. Nusyirwan dan S. Ilham, “Study of Improving Fracture Toughness of Un-Saturated Polyester with Addition of Mixing Percentage of CPO Oils,” vol. 2, hal. 132–137, 2022.

[9] H. Ardhyananta *et al.*, “Mechanical and Thermal Properties of Unsaturated Polyester/Vinyl Ester Blends Cured at Room Temperature,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 202, no. 1, 2017, doi: 10.1088/1757-899X/202/1/012088.

[10] J. Njuguna, P. Wambua, dan K. Pielichowski, *Cellulose Fibers: Bio- and Nano-Polymer Composites*. 2011. doi: 10.1007/978-3-642-17370-7.

[11] J. S. Ullett dan R. P. Chartoff, “Toughening of unsaturated polyester and vinyl ester resins with liquid rubbers,” *Polym. Eng. Sci.*, vol. 35, no. 13, hal. 1086–1097, 1995, doi:

10.1002/pen.760351304.

[12] M. T. Albdiry dan B. F. Yousif, "Toughening of brittle polyester with functionalized halloysite nanocomposites," *Compos. Part B Eng.*, vol. 160, no. October 2018, hal. 94–109, 2019, doi: 10.1016/j.compositesb.2018.10.032.

[13] Z. Zulmiardi, M. Sayuthi, F. Safriwardy, dan M. Meriatna, "Uji Mekanik Komposit Serat Daun Nenas Bermatrik Resin Getah Pinus," *J. Teknol. Kim. Unimal*, vol. 8, no. 1, hal. 1, 2021, doi: 10.29103/jtku.v10i1.4160.

[14] J. Jain dan S. Sinha, "Pineapple Leaf Fiber Polymer Composites as a Promising Tool for Sustainable, Eco-friendly Composite Material: Review," *J. Nat. Fibers*, vol. 19, no. 15, hal. 10031–10052, 2022, doi: 10.1080/15440478.2021.1993478.

[15] H. N. Dhakal dan S. O. Ismail, *Unsaturated polyester resins: Blends, interpenetrating polymer networks, composites, and nanocomposites*. Elsevier Inc., 2019. doi: 10.1016/B978-0-12-816129-6.00008-9.

[16] N. Nusyirwan, A. Peronika, H. Abral, H. Dahlan, E. Satria, dan A. Sutanto, "Unsaturated Polyester Fracture Toughness Mechanism With Blending To Vinyl Ester and Mma," *ARPN J. Eng. Appl. Sci.*, vol. 17, no. 23, hal. 1990–1996, 2022.

[17] H.Abral, R.Fajrul, D. H. M.Mahardika, E.Sugiartii, dan A.N.Miuslim, "Nanovoids in fracture surface of unsaturated polyester/vinyl ester blends resulting from disruption of the cross-linking of the polymer chain networks," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1062, no. 1, 2021, doi: 10.1088/1757-899X/1062/1/012051.

[18] K. Liu, S. He, Y. Qian, Q. An, A. Stein, dan C. W. Macosko, "Nanoparticles in Glass Fiber-Reinforced Polyester Composites: Comparing Toughening Effects of Modified Graphene Oxide and Core-Shell Rubber," *Polym. Compos.*, vol. 40, no. S2, hal. E1512–E1524, 2019, doi: 10.1002/pc.25065.