R.E.M. (Rekayasa Energi Manufaktur) Jurnal | Vol.9 No.2/2024
ISSN online (2528-3723)
http://doi.org/10.21070/rem.v9i2.1704

Analysis of the Strength Thorn Pandan Leaves Fiber Composite: Woven Vs Random Fibers

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Article history: Received: 2 May 2024 | Revised: 8 December 2024 | Accepted: 9 December 2024

***Abstract**. This study focuses on assessing a composite material that uses pearly leaf reinforcement and a polyester resin matrix as a construction material for energy-efficient automobile bodies. The traction strength test and impact resistance test of thorn panda leaf fiber are conducted to evaluate the difference in fiber direction, namely induced and random. This discovery is anticipated to be advantageous for the development of energy-efficient automobile bodywork. The highest traction force recorded is 2199.63 MPa in the random fiber direction, whereas the lowest traction strength is 2077.43 MPa in the fiber direction. The pulling force increases when the direction of the fiber aligns with the pulling manner, resulting in more force. The impact's greatest absorbent energy strength is 0.623 j in the direction of the fiber, while the least absorbent energy strength is 0.595 j in the direction of the random fiber.*

Keywords: *Composites, impact test, pineapple leaves, tensile test.*

METHODS

The Shell Eco-Marathon (SEM) is a sponsored competition by Shell where automobiles compete to achieve the highest fuel efficiency. The competition encompasses two distinct types of public vehicles: prototype vehicles and urban concept vehicles. Participants in the prototype category must create, construct, and race cars with a streamlined body shape to minimize air resistance, while prioritizing the safety of drivers and other vehicles[1]. The car's body is a crucial component that must be constructed with robustness in order to safeguard the driver and internal components. The car's body construction is typically constructed from robust steel, designed to efficiently absorb impact energy. Proficiency in body design and material selection is crucial for developing a body that is both lightweight, pliable, and robust. The car's body is made of composite or natural fiber material, which was selected for its lightweight properties in comparison to steel or iron plates, making it an ideal choice for constructing an electric vehicle. The vehicle's weight impacts the amount of energy it emits. If the weight exceeds a certain threshold, then the amount of energy released is very high[2].

With the advancement of technology and science, humans have developed advances in the use of composite material technology to create materials of superior quality compared to earlier ones[3]. The swift advancement of this technology has led to the substitution of synthetic materials with natural fiber-based materials in composite materials. This substitution allows for the production of lightweight, durable, cost-efficient, and eco-friendly renewable materials. However, it should be noted that synthetics are not entirely devoid of functionality. Although we have discontinued the use of composites, there is considerable potential in the development of composites based on natural fibers[4]. The advancement of composite materials in the field of engineering has been fast in recent times. Composite materials have the benefit of having a superior strength-to-weight ratio compared to metals[5].

The pineapple leaf fiber is a naturally occurring fiber abundant in Indonesia. The thorn pandan plant, a member of the Pandanaceous family, thrives in mountainous areas and along the coastal river in the village of River Toman, district Salat Triple. Thorns have many branches, with leaves that are predominantly green, a leaf length of about 50–200 cm, and a leaf width of 4 cm. There are sharp thorns on the leaf's right-left edge and middle bottom. Many industries use thistle plants to produce fabrics, sculptures, ticks, and medicines.

Composite material research continues to develop; some research has been done on natural composite materials to find out the mechanical properties of materials[6]. The tested natural fibers include coconut fiber[7], coriander peel, bamboo fiber[8], banana stem fiber[9], and pineapple fiber[10]. People often use natural fibers due to their abundance and low cost. Therefore, we typically use them as reinforcers, such as almond fiber. The thorns have tape-shaped leaves measuring 7–250 x 3–9 cm, green, with dust at the ends of the leaves, sloping to the end[11].

Pine leaves are one of the most widely spread in open areas and low plains. Strong fibers in these leaves, which can reach lengths of 1 to 3 meters and widths of 2 to 16 cm, make them a popular choice for textile raw materials. Usually, this species grows on a sloping shore and forms a dense herd[12].

Thistle leaf fiber is one of the alternative natural fibers for composite material production, and its uses are constantly evolving to produce more perfect composite materials in the future. Decomposing the leaves of the duri allows for the easy removal of the fiber from the other parts of the leaf. Researchers use this fiber as a reinforcer in the manufacture of composite materials. The leaf fiber of the thistle has a mass of 0.96 g/cm3[13].

Epoxy resins, widely used as a base material for various handicrafts, are very easy to obtain. Epoxide resins can also serve as coatings on wood or iron due to their resistance to fluid absorption after preservation[14].

We perform the pull test to measure the length and pull strength of the matrix fiber and composite fiber. Insert the test object into the machine and gradually increase the load until the test item fails. This test complies with ASTM D-638M-84 M-1 standards. Based on its durability properties, the impact test determines if a material is fragile or flattened by the movement of an object[11].

According to Rachman and Aditiya, "the maximum pulling strength is 41.33 MPa in the vertical fiber direction, while the minimum pulling force is 8.44 MPa in the horizontal fiber direction. This is due to the increased amount of fibers and the influence of the fiber orientation on the traction style, thus increasing the force of traction. We achieve the maximum impact strength in the vertical direction at 0.0616 J/mm^2, and the minimum impact force in the horizontal fiber direction at 0.0216 J/mm^2[11]

The goal of making a composite is to improve certain mechanical or specific properties, facilitate difficult-to-manufacture designs, and increase the availability of a form or design that can save production costs and make the material lighter. An agency or factory can typically predict the mechanical properties of a composite material based on matrix materials and reinforcements. This study, related to previous research, is intended to understand and know the strength value of the pineapple leaf fiber leaf with random and random models. The manufacturing industry can use the study's results to produce products like car bodies.

METHODS

This research uses experimental methods. The experiment was to produce a composite material reinforced with peppermint leaf fiber. The aim of this study was to find out the impact of the variation of anyam fiber and random fiber optimum for composite reinforcing with pepper sheet fiber. We weigh the fibers according to a 30% volume fraction, cut them according to the sample size, and then chop them into columns. Tests were conducted to determine the difference in strength of the pineapple's fiber leaves with the variation of anyam and random fiber. The study conducted three repetitions of a single material testing process, resulting in a total of 12 test samples. The results of these three tests are the average values of the pull and impact tests. We use the method to determine the traction and impact strength of the pineapple leaf fiber, which serves as a bound variable for creating an energy-efficient car body, by utilizing a polyester resin matrix with random and random fiber variations.

A. The process of making a test object or specimen

In the process of manufacturing the test object or sample, there are several stages, namely the processing of raw materials such as fiber, leaves of thorns, polyester resins, and catalysts. We gather the leaves from the orange garden, then undergo a 20-day immersion process to extract the duri leaf fiber. Next, we separate the fiber from the meat by slowly chewing with a tablespoon, ensuring the fiber remains intact when separated from the leaf flesh. Following the separation process, we wash the meats in clean water until they are clean, and then dry them in the sun. These specimens are manufactured with two differences in the fiber model: random and unrandom fiber. We manufacture the test objects using ASTM D 638M–84 M-I standard sizes for traction tests and ASTM 179-1 for impact tests. We construct the sample using a 30% fiber volume and a 70% polyester composite. Prepare the tool and material, then apply wax processing to First, get the tool and material ready. Then, use wax to make it easier to remove the test object from the mold after it has dried. Put each material into the mixing container based on its composition, removing some of the polyester resin and adding the catalyst based on its composition into the blender container. Mix until the resent, we use a compressor to compress the material, and we let it dry in the sun for approximately 24 hours. If the material doesn't dry completely, we can extend the drying period. We then use a knife or cutter to shape the printed composite into a test object, adhering to each test's standards. Adres of each test.

Figure 1. The specimen casting process

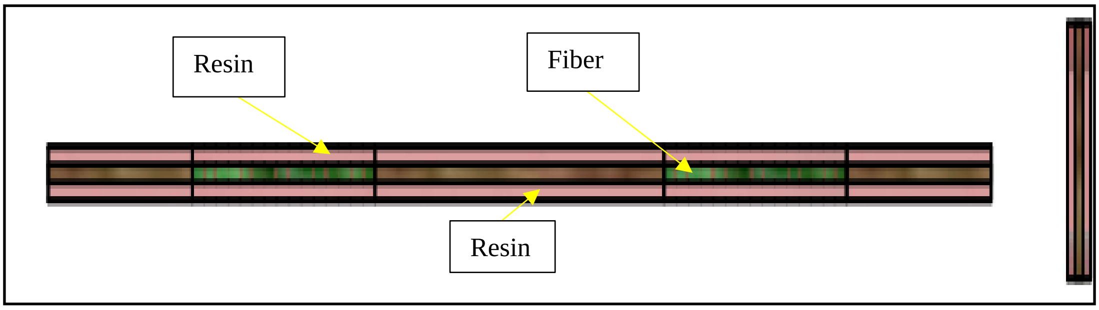

Figure 2. Position of resin and fibers in tensile test

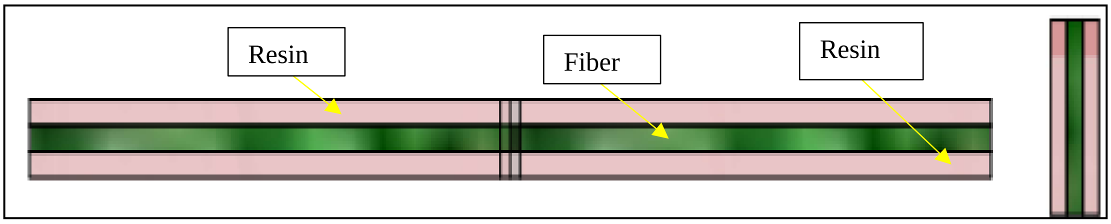

Figure 3. Position of resin and impact test fibers

Figures 2 and 3 are the sightings after the casting, which layers 1 resin, 2 fibers, and 3 resins.

B. Matrix and fiber volume ratio calculation

In the manufacture of traction test specimens, calculations are required to determine the volume ratio between the matrix and the fiber when making traction test specimens[11].

The formula for determining a fiber type's mass is:

$$\rho = \frac{m}{v} \quad ....(1)$$

Description:

ρ = Fiber Type Mass (g/cm³)
m = Fiber Mass (g)
v = Fiber Volume (cm³)

The mass type of fibers multiplied by the composite volume formula yields the mass of composite fibers, which is in line with the formula equation[11].

$$m_{fc} \times \rho_{fc} \times x_{fc}\% \quad ....(2)$$

Description:

M_{fc} : Composite Fiber Mass (g)
V_{fc} : Composite Fiber Volume (cm³)
ρ_{fc} : Composite Fiber Density (g/cm³)
$x_{fc}\%$: Fiber volume fraction

The formula for calculating the mass of a composite matrix is the volume of the composite matrices multiplied by the mass of the metric type; this corresponds to the formula's equation. [8]

$$M_{mc} \times V_{mc} \times x_{mc}\% \quad (3)$$

Description:

M_{mc} = Composite Matrix Mass (g)
V_{mc} = Composite Matrix Volume (cm³)
ρ_{mc} = Composite Matrix Density (g/cm³)
$x_{mc}\%$ = Matrix Volume Fraction

The calculation of the pull test specimen had a mold volume of 9.78 cm3, and the impact test specimens had a stamp volume of 3.2 cm3, a resin type mass of 1.215 g/cm3, and a catalyst type mass of 1.25 g/cm3 [11].

C. Tensile and impact strength testing

Figure 2 shows traction testers using the ASTM D 638M-84 M-I composite material test standard, along with the size of the printing.

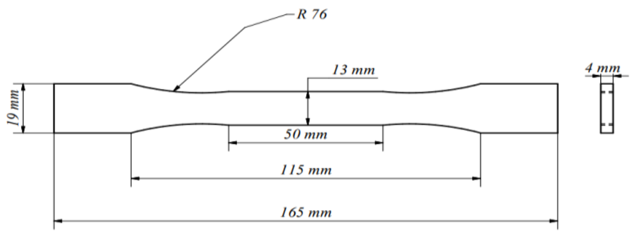

Figure 4. Design specimen conforms to ASTM D 638M

Figure 5. Tensile test specimen

The ASTM 179-1 impact test was used. Figure 3 displays the print size.

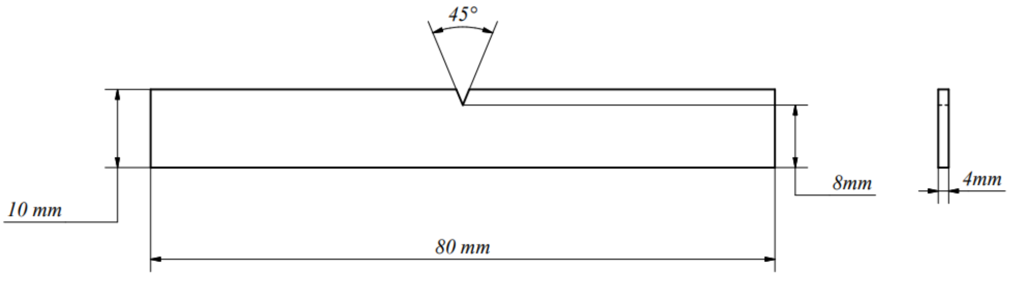

Figure 6. Specimen Dimensions Standard Impact Test ASTM 179-1 [15]

The impact strength of the test object can be calculated using the equation:[11]

$$HI = \frac{E}{A} \quad (4)$$

Description:

HI = Impact strength (J/mm2)
E = Absorption/fracture energy of the specimen (joule)

A = The cross-sectional area of the specimen below the notch (mm^2)
M = Pendulum Weight (m)
g = Gravity 9.81 (m/s^2)
r = The distance of the pendulum to the center of rotation (m)
Cos α = Pendulum angle without test object (°)

Figure 7. Impact test specimen

RESULTS AND DISCUSSION

This study used the dust leaf's fiber, varying its direction in both random and unrandom ways. We conducted traction tests using the Universal Testing Machine and impact tests using the JB-300 B. We obtained and processed the data to produce a diagram and conclusion about the variation of the fiber's direction, which will determine the force of traction and impact.

In the process of research using duri leaf fiber, the direction of anyam and random fiber was compared. We conducted tests to determine the strength of leaf duri fiber, taking into account variations in direction and random fibers. This study conducted three repetitions of a single material testing process, resulting in a total of 12 test samples. These three tests produce average values for the pull and impact tests.

A. Tensile test results

The pull test was performed on the Universal Testing Machining model. Where the pulling force value is automatically obtained for each cut specimen. The pulling power value is shown in the table below:

Table 1. Tensile strength test results

No	Fiber direction	sample	Matrix and fiber volume ratio (%)	Pull force (N)	Tensile stress (N/mm^2)
1.	Woven	1.	70:30	2199,63	43,05
		2.	70:30	1833,03	35,46
		3.	70:30	2199,43	41,59
	Average			2077,43	40,03
2.	Random	1.	70:30	2199,63	38,73
		2.	70:30	2199,63	37,33
		3.	70:30	2199,63	42,07
	Average			2199,63	39,37

The drawing voltage chart below shows the outcome of the polyester composite's traction test with fiber reinforcer leaves:

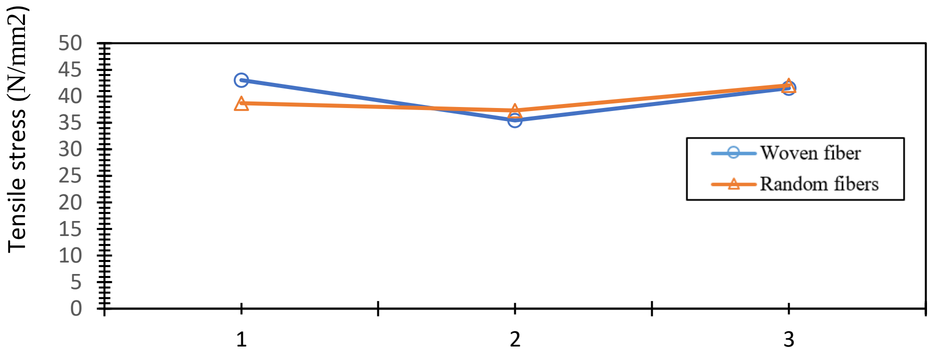

Figure 8. Tensile stress graph

According to the chart above, the pull voltage indicates an increase in the fiber in sample 1, which is 43.05 N/mm2. After carrying out the pull test, we obtained the average results in Table 1. Whereas a composite with a direction of fiber can withstand a load of 2077.43 N, the load is smaller compared to the direction of a random fiber. However, a compound with a fiber direction has a greater pull strength than a compound with a combined direction of 40.03 N/mm2 and a stretch of 0.01727.

Table 2. Average test results of raw and random fibers

No	Composite with fiber direction	Max Pull force (N)	Tensile stress (N/mm^2)	Strain
1.	Woven fiber	2077,43	40,03	0,01727
2.	Random fibers	2199,63	39,37	0,01358

Based on table 3, composites with a random fiber direction can withstand loads up to 2199.63 N and a stretch of 0.01727; the loads are larger compared to the direction of the fiber. But the compound with the random fiber direction has a smaller pull voltage compared with the composite with the fiber direction, which is 39.37 N/mm2, and the stretch is 0.01358. Figure 4 displays the graph of the compound traction test result with the random fiber direction.

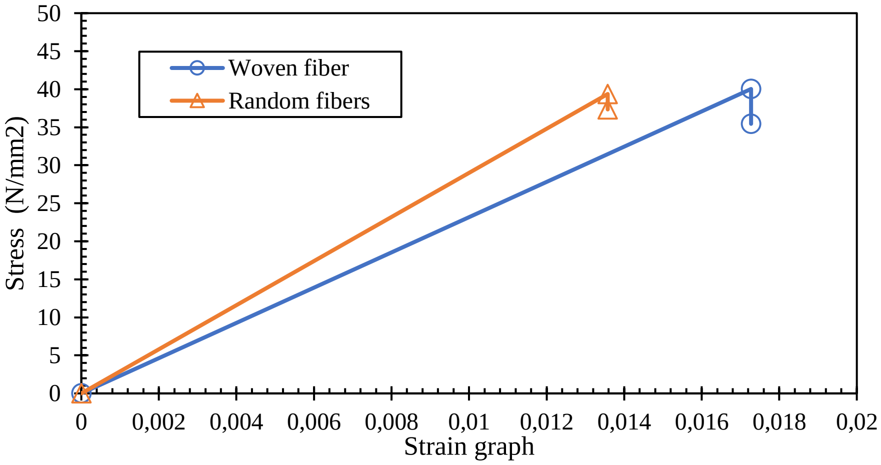

Figure 9. Stress and strain graph

Figure 4 above shows a graph of tension between composite materials with different fibers, namely random fibers. As you can see from the graphs for both models, the fibers have different trends. For composites with any fiber, there is a maximum pull voltage of 40.03 N/mm2.

Figure 10. Specimen after tensile testing

A. Impact test results

We perform impact tests to determine the resistance of specimens of composite or metal materials. We conduct the impact test using the Charpy impact testing machine, model JB-300B. The test uses the ASTM 179-1 standard. The test object absorbs energy in joule units, which is the result of the impact resistance test.

Table 3. Impact resistance test results

No	Fiber direction	sample	Matrix and fiber volume ratio (%)	Absorb Energy (J)	Impact strength (J/mm^2)
1.	Woven	1.	70:30	0,599	0,0150
		2.	70:30	0,652	0,0163
		3.	70:30	0,618	0,0155
	Average			0,623	0,0156
2.	Rendom	1.	70:30	0,650	0,0163
		2.	70:30	0,645	0,0161
		3.	70:30	0,491	0,0123
	Average			0,595	0,0149

Table 3 above provides data indicating that the directional variation of the used fiber will influence the impact test strength of each test specimen, with the data values revealing varying results. The table above reveals an average energy absorption of 0.623 joules in the fiber direction specimen. On the other hand, the average energy absorbed in specimens oriented randomly is 0.595 joules. From the obtained data, it is evident that the direction of the fiber significantly influences the absorption energy.

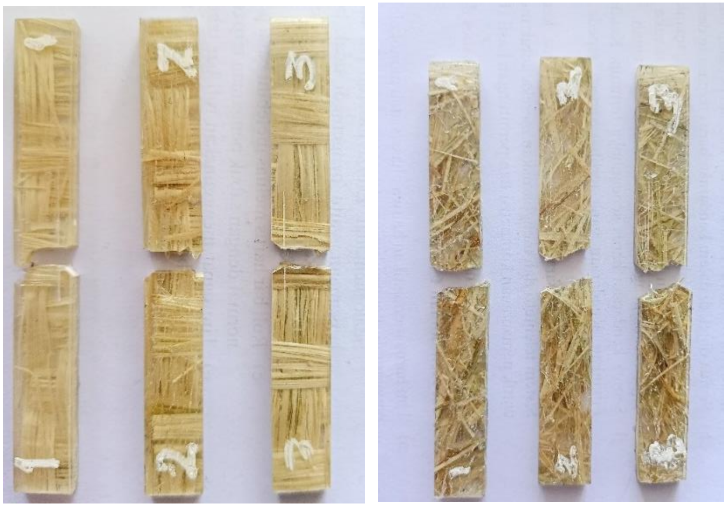

Figure 11. Specimen after impact testing

B. Explanation of pull and impact testing using a microscope

An optical microscope with a 50-fold magnification analyzed the fragmentation of the sample. The objective is to explain how the bonds between the fiber of the thruster and the polyester matrix work. Besides, the type of fracture that occurs on the composite fiber of the dredge leaf must also be known. Each fiber has a different type of bond. The better the relationship between fiber and metric, the stronger its material composition.

The picture below shows a micrograph of a composite pull specimen 50 times the fracture cross-section. The results of the test showed that the fiber fracture was random in the pull test.

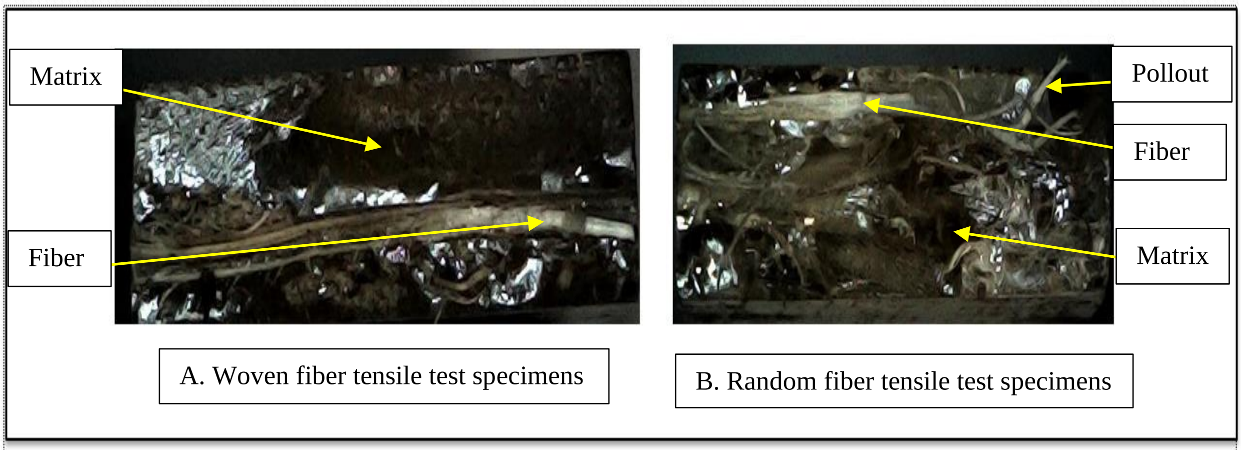

Figure 12. Microphotography of a broken intersection of the pull test specimen with 50-fold magnification

At 50-fold magnification, Figure 6 shows a microphoto of break-up glue from a composite pull test specimen. The leaf fibers are light gray, while the martic is black to brown. The shiny colors in the photo indicate a rubber fracture, whereas the dim color indicates a compound fracture. From the photo, we can determine that the composite with a fracture in the fiber is an acrylic composite. The composite exhibits the features of a fractured fiber, such as a hazy surface and a dimple. Because it has a glossy surface.

We analyzed the fractures in the sample using a 50-fold magnification microscope. The aim is to find out what kind of bond there is between the fiber leaf and the impact matrix of the test object. Also, find out the type of fracture that occurs on the composite fiber of the leaf. The picture below refers to a micro-intersection fragment of an impact test specimen.

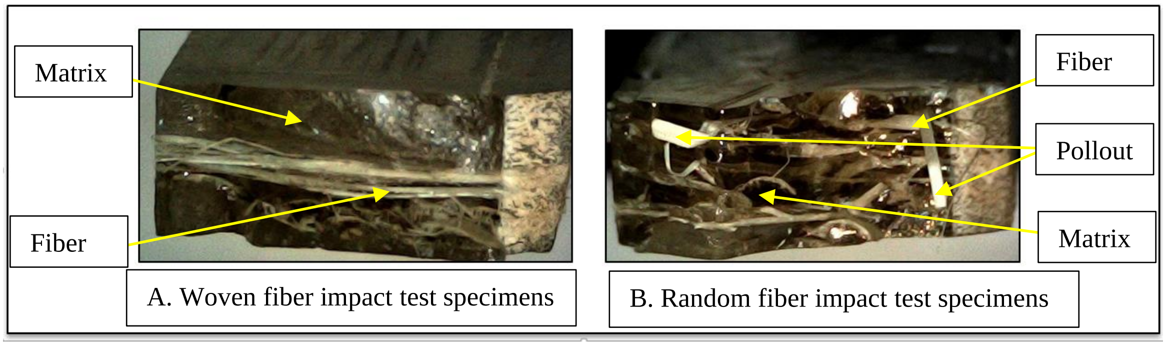

Figure 13. Microphotography of the impact test specimen crossing with 50-fold magnification

Picture 7 microfotos of fracturing specimens from the impact test, on the microfoto above the fiber fracturer of anaman, showing the bonding of the fiber leaf of a duti leaf with a fairly good matrix. The evidence is evident at the point where a broken fiber intersects, and no fiber escapes, indicating a well-anchored voltage distribution. This type of fiber direction rupture is known as a fiber fissure rupture, as evidenced by the presence of a dimle and a blurred surface in the microphoto. Microphoto fiber directions rupture intersection random fiber bonding with a martic is not good because the fiber appears to be attracted out. (pollout). This proves that the bonding of the pineapple's surface fiber leaves with the polyester martic is not good. This type of random fiber fracture is called a rubber fracture because it has a glossy surface.

CONCLUSION

In the traction and impact testing of two specimen models, specimens with anyam models have greater traction test values and impacts compared to random models. This is due to the microtest results, where anyam fibers have more uniform fiber bonds between metric fibers while the specimen model with random fibers appears to have some fiber that is attracted out. This proves that with random fiber models, the fiber bonds are uneven and less good.

REFERENCES

[1] D. Suherman, "ANALISA SISTEM PENGEREMAN KENDARAAN MOBIL HEMAT ENERGI SESUAI REGULASI SHELL ECO MARATHON 2022," 2023.

[2] O. Andriyanto and R. Krisnaputra, "Proses Pembuatan Bodi Komposit Dan Analisa Kekuatan Material Komposit Mobil Listrik Yacaranda," *Univ. Gadjah Mada*, 2018.

[3] R. L. Pambudi and H. Yudiono, "Pengaruh Orientasi Sudut Serat Pandan Duri Terhadap Ketangguhan Impact Komposit Sebagai Material Alternatif Bumper Mobil," *J. Kompetensi Tek.*, vol. 12, no. 2, pp. 21–29, 2020, doi: 10.15294/jkomtek.v12i2.23329.

[4] W. A. Wirawan, S. A. S. Budi, and T. D. Widodo, "Pengaruh Jenis Matrik Terhadap Sifat Tarik Pada Natural Fiber Komposit," *Politek. Negeri Malang*, vol. 3, no. January, pp. 2476–9983, 2017.

[5] P. N. Dwi Hartini1, Lazuardy Rahendra Pinandita2 and Mubarak3, "Tensile Strength Analysis of Sea Pandan Leaves (Pandanus Tectorius) Fiber Reinforced Epoxy Composite," *Vortex*, vol. 3, no. 2, p. 108, 2022, doi: 10.28989/vortex.v3i2.1242.

[6] A. Rahman, M. Farid, and H. Ardhyananta, "Pengaruh Komposisi Material Komposit dengan Matriks Polypropylene Berpenguat Serat Alam Terhadap Morfologi dan Kekuatan Sifat Fisik," *Tek. ITS*, vol. 5, no. 2, pp. 209–211, 2016.

[7] B. Maryanti, A. A. Sonief, and S. Wahyudi, "Pengaruh Alkalisasi Komposit Serat Kelapa-Poliester Terhadap Kekuatan Tarik," *Rekayasa Mesin*, vol. 2, no. 2, pp. 123–129, 2011.

[8] S. Djamil, Sobron Y Lubis, and D. Hartono, "Kekuatan Tarik Komposit Matrik Polimer Berpenguat Serat Alam Bambu Gigantochloa Apus Jenis Anyaman Diamond Braid dan Plain Weave," pp. 1–8, 2014.

[9] E. Apriani, "Analisa Pengaruh Variasi Komposisi Bahan Limbah dari Serat Kelapa Muda, Batang Pisang dan Kertas Bekas terhadap Kekuatan Bending Sebagai Papan Komposit," *J. Engine Energi, Manufaktur, dan Mater.*, vol. 1, no. 2, p. 38, 2017, doi: 10.30588/jeemm.v1i2.259.

[10] L. Diana, A. Ghani Safitra, and M. Nabiel Ariansyah, "Analisis Kekuatan Tarik pada Material Komposit dengan Serat Penguat Polimer," *J. Engine Energi, Manufaktur, dan Mater.*, vol. 4, no. 2, pp. 59–67, 2020.

[11] A. Rachman, "VOLUME SERAT PANDAN DURI TERHADAP," 2022.

[12] M. Muhammad and R. Putra, "Uji Mekanik Komposit Berpenguat Serat Pandan Duri dan Resin Polyester Dengan Variasi Komposisi Metoda Fraksi Berat," *J. Teknol. Kim. Unimal*, vol. 6, no. 2, p. 63, 2018, doi: 10.29103/jtku.v6i2.476.

[13] P. Widianto, "Prgram studi teknik mesin fakultas teknik universitas muhammadiyah surakarta 2020," 2020.

[14] M. H. Alamsyah and G. Gundara, "Analisis Sifat Mekanik Komposit Bahan Kampas Rem Dengan Penguat Serbuk Kayu Jati Dan Serbuk Kuningan," *R.E.M. (Rekayasa Energi Manufaktur) J.*, vol. 5, no. 1, pp. 9–13, 2021, doi: 10.21070/r.e.m.v5i1.870.

[15] Arbi Syahrian, "TERHADAP KEKUATAN TARIK DAN IMPAK KOMPOSIT RESIN BERPENGUAT SERAT RESAM," 2022.

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