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Fabrication of polymer matrix composites by bagasse based on Yukalac polyester resin

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ABSTRACT

The natural fibre containing cellulose as its main component that can be used as an alternative material to improve the strength of polymer composites. Paper focused on the determination of the best volume fraction of sugarcane fibre-reinforced polymer composites. Three variants of alkalization time were carried out. The highest average value of the tensile test results was obtained at an alkalization time of 1.5 h with a tensile strength of 41 N mm^{-2} and elongation correspond to 11.806% where the highest bending test results were obtained at an alkalizing time of 0.5 h with a bending strength of 24.89 N mm^{-2}. The results of mechanical interlocking have been observed on macrostructure photo and at 1.5 h of alkalization are better than 0.5 h and 1 h of alkalizing time.

KEYWORDS

bagasse, yukalac polyester resin, polymer composite, alkalization time, mechanical interlocking

1. INTRODUCTION

Composite is a simple arrangement of materials consisting of a combination of several different materials by consisting of two or more different materials. Mixture of materials on a macroscopic scale has been used to form unique new materials with superior and more useful properties. Composites and alloys have differences in the way they are combined, namely when the composites are combined macroscopically where the fibers and matrix are still visible (fiber composites) and the alloys were combined microscopically while the supporting elements are no longer visible [1, 2]. The use and utilization of alloy and composite materials is currently growing. These composite materials are increasingly widespread in most of the engineering applications ranging from simple ones until household appliances to the industrial sector, both small-scale and large-scale industries. Composites have distinct advantages compared to alloy materials, including: light weight, smooth surface, long service life, corrosion resistance, wear resistance, impact resistance and good formability. Natural fiber is one of the alternative natural fiber materials in the manufacture of composites where scientifically its use continues to be developed [3–5].

The country of Indonesia, which is located in the tropics with its population growing crops in rural areas, is one of the largest sugar canes producing countries. With a land area of 3,738.16 km^2 in 2020 with a sugarcane income of 8.5 kg m^{-2} from the sugar processing process

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by only taking the water, while 35–40% of the weight of milled sugarcane in the form of fiber dregs is only used as industrial fuel and some waste materials disposed of as waste. Natural fibers are starting to be seen by their users because in addition to being easy to obtain, cheap, can reduce environmental pollution, so that by making composite materials this will be able to overcome environmental impact problems and not endanger health [6]. Sugarcane contains extractive substances, especially sugar or starch, which it can inhibit the gluing process and can reduce the mechanical properties of the composite materials.

According to [7] and [8], extractive substances affect the consumption of adhesive, the rate of hardening of the adhesive and the durability of the resulting particle board. On the experiment used bagasse fiber which may not have been able to be utilized so far to become a product with maximum benefits and high selling value.

This research work was conducted to obtain data on mechanical and physical capabilities in the form of tensile and bending strength as well as macro and micro descriptions. Based on this research results we will be able to be applied and to produce a more useful composite material in different engineering applications.

2. MATERIALS AND METHODS

In Fig. 1 it has been shown the composite materials preparation, which is composed from bagasse base material, NaOH, Yukalac 157 polyester resin BQTN-EX and trade mark polymer called Methyl Ethyl Ketone Peroxide (MEKPO).

The sugarcane fibers have been washed to remove adhering dirt, then dried in the sun. Afterward the oven process has been used to reduce the water content. NaOH is used to remove dirt or lignin from the fiber. NaOH is an alkaline solution and looks slippery. In the next step it has been used Polyester Resin type Yukalac 157 BQTN-EX as matrix, which was obtained commercially an additional catalyst that functions as a resin hardener. At the end of materials preparation, it has been used the glass wax that is in function as a coating for composite molds to remove easily, and catalyst under the MEKPO trademark is also used as an adhesive.

The process of working on specimens using the wet hand lay-up method is carried out using a catalyst mixed with 1% of the resin by weight of the resin and then stirred until smooth, applying the first resin layer to the mold. Afterward the weighed fiber is placed on it, which has been repeated this work until the specified fiber and resin were used up. Furthermore, after a few hours later the sample has dried and removed by cutting according to the provisions on the tensile test specimen and bending test [9–17]. Samples were made using the wet hand lay-up method with a ratio of resin and bagasse, presented in Table 1 and Fig. 2.

3. RESULTS AND DISCUSSIONS

3.1. Mechanical properties of composite bagasse based on Yukalac polyester resin

In Tables 2 and 3 show the data of woven sugarcane fiber as a reinforcement in polymer composites that has been obtained from the tensile test and bending test results.

In accordance to the variables of alkalization time and volume fraction used, the graph of the relationship between tensile strength and volume fraction and time of alkalization is shown in Fig. 3 and the graph of the relationship between bending strength with volume fraction and time of alkalization is shown in Fig. 4. Tensile test obtained the highest average tensile strength value at the time of alkalization of 1.5 h with a volume fraction of 10%: 90% at 41 N mm^{-2} and the lowest average value of tensile strength at an alkalizing time of 0.5 h with a volume fraction of 15%: 85% of 29.86 N mm^{-2}. In this tensile test, the highest average % elongation value was found at an alkalizing time of 1.5 h with a volume fraction of 10%: 90% at 11.806% and the lowest % elongation average value at an alkalizing time of 0.5 h with a volume fraction of 15%: 85% of 9.117%.

According to [18] decay of lignin on the fiber surface will increase the mechanical properties of the fiber and increase the mechanical interlocking at the fiber-matrix interface. However, too long alkalization time will result in excessive decay of lignin and hemicellulose so that the bonds between micro-fibrils are damaged. This will further reduce the

a) b) c) d)

Fig. 1. a) Bagasse base material b) NaOH, c) Yukalac 157 polyester resin BQTN-EX, d) MEKPO (*Source*: Polymer and Composites Laboratory at the Center of Excellence, Faculty of Engineering, University of Sultan Ageng Tirtayasa)

Table 1. Lamina configuration 200 × 168 × 5, volume fraction 15–25%

Layer	Configuration	Weight VF 15% (g)	Weigh VF 20% (g)	Weight VF 25% (g)
1	Resin	78.54	73.92	69.30
2	Bagase	4.54	6.01	7.56
3	Resin	78.54	73.92	69.30
4	Bagase	4.54	6.01	7.56
5	Resin	78.54	73.92	69.30
6	Catalyst	2.30	2.20	2.00

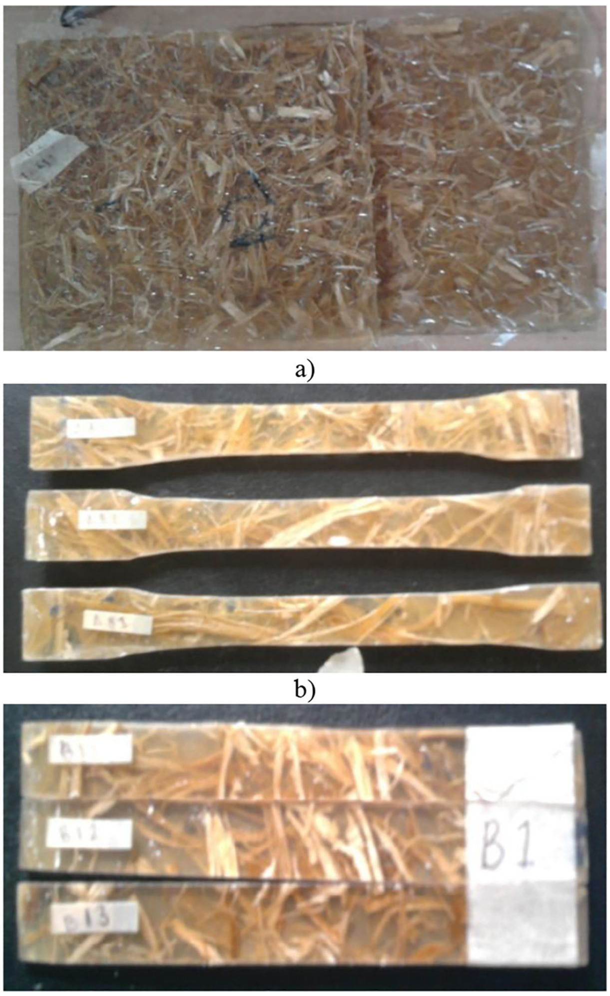


Fig. 2. a) Sugarcane fiber composite mold results with polyester matrix; b) sugar cane fiber composite tensile test sample; c) sugarcane fiber composite bending test sample (*Source*: Metallurgy Laboratory at Faculty of Engineering, University of Sultan Ageng Tirtayasa)

mechanical properties of the fiber and its composites. At 1.5 h of the alkalization process, the fiber surface components that were less effective in determining the interface strength, like hemicellulose and lignin, has been decayed more than the 0.5 h of the alkalization process and were not excessive. The effect of alkali treatment on the surface properties of natural cellulose fibers and the hydrophilic nature of the fibers can provide optimal interfacial bonds with the matrix.

Table 2. Tensile test result data

No.	Alkalization time (h)	Volume fraction (%)	Tensile strength (N mm^{-2})	Elongation (%)
1	0.5	10–90	31.66	10.522
2	0.5	15–85	29.86	9.117
3	0.5	20–80	30.60	9.359
4	1.0	10–90	39.70	11.758
5	1.0	15–85	34.46	10.541
6	1.0	20–80	38.76	10.515
7	1.5	10–90	41.00	11.806
8	1.5	15–85	33.41	10.792
9	1.5	20–80	30.70	9.462
10	received	Reinforced	29.10	8.785

From the above results mentioned in Figs 3 and 4 it have been seen that the three times of the alkalization process was carried out where the trend formed for the tensile strength and % elongation values after the increase in the reinforced volume fraction tended to decrease, this was due to the inhomogeneity of the amount of reinforced in each specimen which resulted in different results of the test values in one variable which was quite large in difference. And the reinforced arrangement of each specimen is not entirely straight, but there are some that are slightly twisted and this causes the transformation of the load absorbed by the specimen to be not good.

The bending test in this study obtained the highest average bending strength at an alkalizing time of 0.5 h with a volume fraction of 15%: 85% at 24.89 N mm^{-2} and the lowest average value of bending strength at an alkalizing time of 1.5 h with a volume fraction of 20%: 80% of 22.43 N mm^{-2}. The trend that was formed at the alkalizing time of 0.5 and 1.5 h increased at 15%: 85% volume fraction and then decreased at 20%: 80%. For the 1-h alkalization time, it decreased to 15%: 85% volume fraction and then increased to 20%–80% volume fraction. This happens due to the inhomogeneity of the amount of reinforced in each specimen which will also result in different amounts of mechanical interlocking formed and will result in different results of test values in one variable with a quite large difference. Furthermore, the reinforced arrangement of each specimen is not entirely straight but some are slightly twisted and this causes the transformation of the load absorbed by the specimen to be not good.

3.2. Observation of macro-structural faults

Observation of the macro-structure was carried out using an optical microscope with a magnification of 10 × which aims to be able to see the mechanical interlocking formed. In the 0.5-h alkalization process, the average value of the highest tensile test results was obtained with a tensile strength of 31.66 N mm^{-2} and elongation correspond to 10.522%. The average value of the highest tensile test

Table 3. Bending test result data

No	Alkal. time (h)	Volume fract. (%)	Load (N)	Deflection (mm)	Bend. momen (N mm)	Strength (N mm^{-2})
1	0.5	10–90	56.85	2.584	923.81	24.74
2	0.5	15–85	57.20	2.398	929.50	24.89
3	0.5	20–80	55.45	2.191	901.06	24.13
4	1.0	10–90	52.20	2.348	848.25	22.72
5	1.0	15–85	51.65	2.390	839.31	22.48
6	1.0	20–80	56.45	2.320	917.31	24.57
7	1.5	10–90	51.90	2.217	843.37	22.59
8	1.5	15–85	55.05	2.350	894.56	23.96
9	1.5	20–80	51.55	2.238	837.68	22.43
10	received	Reinf.	56.90	2.650	924.62	24.76

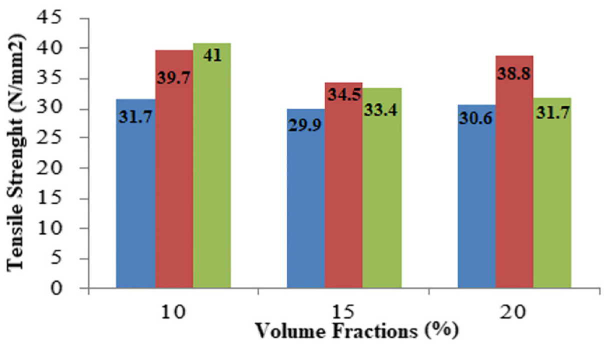


Fig. 3. Graph of the relationship between the time of alkalization and the volume fraction of the tensile strength of the tensile test result

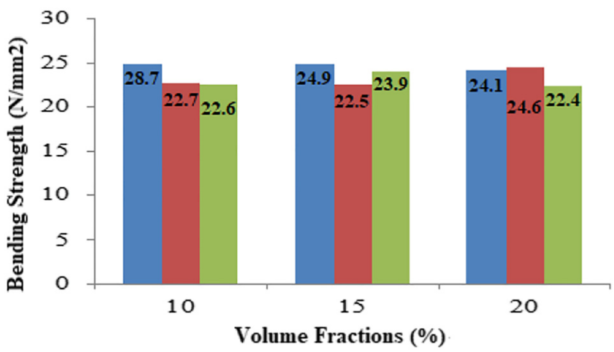


Fig. 4. The relationship between alkalization time and volume fraction on bending test results

results in the 1-h alkalization process tensile strength correspond to 39.7 N mm^{-2} and elongation to 11.758%. Afterward in the 1.5-h alkalization process, the average value of the highest tensile test results with tensile strength correspond to 41 N mm^{-2} and elongation of 11.806%. Figure 5 depicts the macro-structure view in the alkalization process.

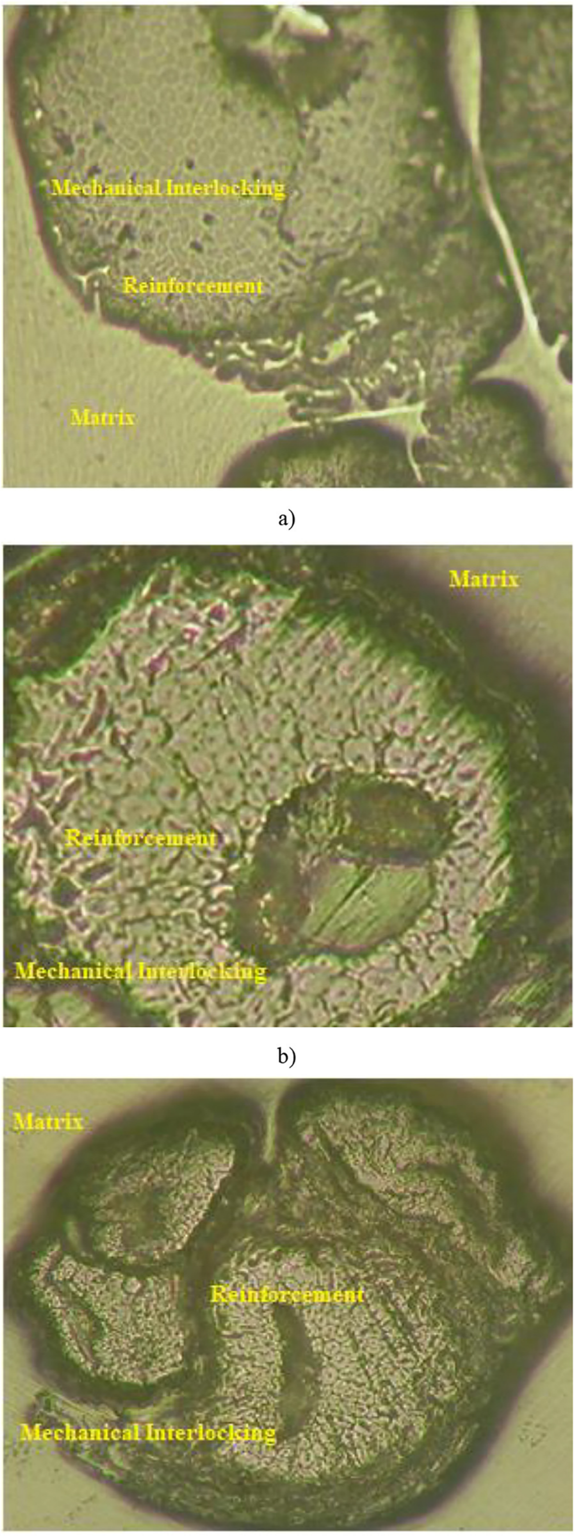
Mechanical interlocking is a mechanical bond formed between the fiber surface and the matrix, which affects the mechanical properties of the bio-fiber composite. Based on the obtained macro-structure photos, it can be seen that the alkalization process resulted in an increase in the morphology of the fiber surface roughness with the length of time of alkalization and improved the mechanical interlocking between the fibers and the matrix formed.

Observation of the microstructure was carried out by metallographic method with an optical microscope with a magnification of 200 ×, of the image in Fig. 6. The observation of this microstructure can analyze the effect of the alkalization process, where it is expected that the resulting composite has a better interface. By results of the micro-photos, it can be seen that the alkalization gave increased roughness morphology of the fiber and improved the mechanical interlocking between the fiber and the matrix. This is in accordance with the phenomenon of increasing tensile strength in the alkalization sample from small to large, which increases with the increase in volume fraction. The matrix can be bonded well with the reinforcement in the form of sugarcane fiber with the formation of an interface around the reinforcement. In Fig. 6 it can be seen the part that corresponds to hollow/porosity and has been caused by less-than-optimal compression during sample preparation which makes the polyester absorption less than perfect.

4. CONCLUSIONS

The results of the research on the strength of the bio-fiber structure of sugarcane fiber composites, some conclusions can be drawn as follows:

- Alkalization method on sugarcane fiber can optimize the strength of the composite bio-fiber reinforced with sugarcane fiber, but alkalizing more than 3% can reduce the strength of the composite bio-fiber with sugarcane fiber reinforcement;
- The average value of the tensile and bending test results decreases with the increase in the number of volume fractions, with mechanical interlocking formed at 1.5 h alkalization time is better than 0.5 h and 1-h alkalizing time;
- The average value of the highest tensile test results was obtained at an alkalization time of 1.5 h with a tensile strength correspond to 41 N mm^{-2} and elongation to 11.806%, and the highest bending test results were obtained at an alkalizing time of 0.5 h with a bending strength of 24.89 N mm^{-2}.



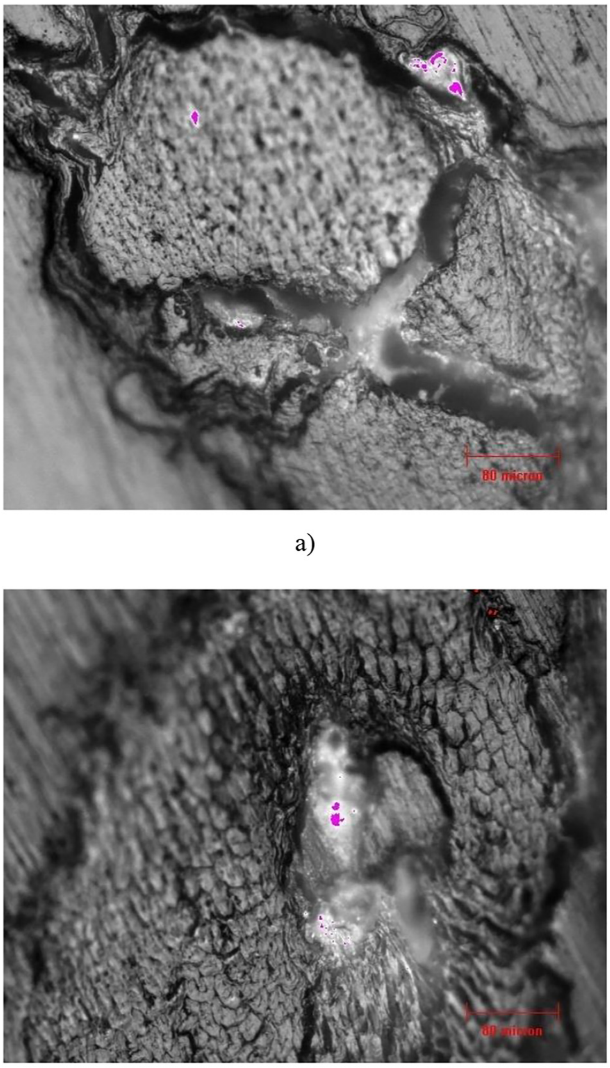
a)

b)

c)

Fig. 5. Photo of macro-structure in the alkalization process: a) 0.5-h; b) 1.5-h; c) 1-h (*Source*: Polymer and Composites Laboratory at the Center of excellence, Faculty of Engineering, University of Sultan Ageng Tirtayasa)

- Perspective on this work is that it is crucial for the assessment of the use of bagasse-based materials for reinforcement in polymer composites in different dimensions



a)

b)

Fig. 6. Composite structure with polyester matrix and sugarcane fiber reinforced, a) 3% alkalization; b) 9% alkalization (*Source*: Polymer and Composites Laboratory at the Center of excellence, Faculty of Engineering, University of Sultan Ageng Tirtayasa)

  microcrystalline, micro fibrillated under low cost energy process.
- Future research is in the form of a follow-up research process by applying simulations to obtain the ideal parameters and theirs application in the industrial world in accordance with the characteristics possessed by both properties.

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