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Effect of Alkalization Duration and the Orientation of Fiber on Composites of Polyester Reinforced Fibre of Terap Tree (*Artocarpus Elasticus*) on Impact and Bending Strength

Composite application has increased in recent years due to many advantages, e.g. In Kalimantan, there are many types of flora, one of which is the Terap tree (Artocarpus elasticus) which has a strong enough strength and is usually used by the Dayak people as clothing, hats, and rigging. In this research, we examine the laminate composite of tree skin fibers against bending strength and impact price. In making composites using a variety of alkali time, namely 60 minutes, 90 minutes and 120 minutes, the amount of alkali concentration used is 15% of the total volume of alkaline liquid. Then also use variations of fiber orientation 0o-90o-0o-90o, 0o-90o-90o-0o, and 90o-0o-0o-90o. The impact test results showed that the highest value was obtained in specimens with an immersion time of 90 minutes with 0o-90o-0o-90o orientation of 0.00294 joule / mm² and the lowest value was found in specimens with immersion time 120 minutes 0o-90o-0o-90o amounting to 0.00164 joules / mm². While the Bending test obtained the highest value in specimens with 120 minutes of immersion time with 0o-90o-0o-90o fiber orientation of 48.01 mph and the lowest value was obtained in specimens with 60 minutes immersion time at 90o-0o-0o-90o for 16.62 MPa.

Keywords: Laminate Composite, Fiber Terap, Time of Alkalization, Fiber Orientation.

1. INTRODUCTION

Composites are comprised of at least two basic components. Composite reinforced by carbon fibre possess similar or higher strength and stiffness [1]. The first one is continuous component called as matrix and the second one is filler serving as reinforcing component. Composite application in engineering purpose has increased in the recent years. Composite is widely applied due to its sound properties, e.g. low weight, high strength to weight ratio, do not rust like metal particularly steel and aluminium. High price and sophisticated production however become the main disadvantage of composites application. More investigated in recent years therefore have been focused on searching for lower cost filler yet still possesses better mechanical properties when combined with its matrix. In automotive industries, composites have been widely applied since the last recent years since it can decrease fuel consumption due to its high strength to weight ratio, high impact strength which increases car safety [2].

Table 1. Properties of selected natural fibres [9]

Fibre	Diameter [μm]	Density [g/cm^3]	UTS [MPa]	Young Modulus [GPa]
Cotton		1.50	500-880	0.05
Jute	200	1.45	460-533	2.5-13
Coir	100-450	1.15	131-175	4-6
Banana	80-250	1.35	529-754	7.7-20.8
Sisal	50-200	1.45	568-640	9.4-15.8
Flax		1.50	1,100	100
Kraft fibre		1.54	1,000	40
Sunhemp	48	0.67	200-300	2.68
Pinneapple	20-80	1.44	413-1,627	34.5

Palm leaf	240		98.14	2.22
Mesta	200	1.47	157.38	12.62
Kusha grass	390		150.59	5.69

Of many alternative reinforcement filler in composites, biodegradable filler has become interesting alternative to support the environmental sustainability in diverse engineering application [1]-[5]. This environmental friendly filler has been applied in biomedical, automotives and packaging industries. Various natural fibres, e.g. cellulose of wood, rice husk, coconut coir and flax [6]-[8], have been studied as reinforcement fiber. Of many natural fibers, flax and kraft fibres show very high tensile strength and elastic modulus (**Table 1**) [9]. Wood cellulose benefits the composites since it is thermally stable, high Modulus Young and good strength [10]-[13]. Natural wood fibres however should be further researched due to its low compatibility with some matrix [14],[15]. Wood fiber is also beneficial in engineering composites application for its high external forced endurance high due to its intertwined network [16],[17].

Wood fiber composites have been extensively studied since beginning of 2000s. The main advantage of wood based composite is environmental friendly since it can be manufactured using wood waste and small sized trees [18]. Additionally, wood based composites can be designed for particular desired mechanical properties depending on natural strength of specific woods, thickness, composition and matrix types. In many cases, wood based composites shows higher strength to weight ratio than regular nature wood. Of many wood source in Kalimantan Islan is terap tree (*Artocarpus elasticus*). For indigenous people in Kalimantan Island, this wood is widely applied as traditional clothing, hats, bags, rigging. The tree of terap (**Figure 1a**) has similarities with the jackfruit tree (*Artocarpus heterophyllus*). The fruits of bot threes can be arguably similar. Wood of terap tree is also used as construction materials particularly as wood beams and boards. An example of an unwrapped fiber can be seen in **Figure 1b**.

Figure 1. a) Terap tree; b) Unwrapped fiber of terap tree

2. RESEARCH METHOD

Skin fibers of Terap tree are boiled, dried then cleaned. After that, the fibers was cut with a length of 98 mm for specimen of impact test specimen and 148 mm for specimen of bending test. After being cut, the fiber experienced alkalization process in 15 wt% NaOH solution for varied immersion duration at 60 minutes, 90 minutes and 120 minutes. Alkalization process is widely applied due to its simplicity, short time preparation and low cost compated than other treatment [19]. Wood fiber contains hemicellulose, pectin, cellulose, and lignin which creastes hydrophilic property of wood fiber [20]. Alkalization process is aimed to improve compactibility between polymer matrix and wood fiber by removing wax, lignin and oil which cover wood fiber [21]. This alkalization also increases roughness of fiber surface to improve interlocking between wood fiber and polymer matrix. After alkalization process, the fiber was washed by Aquades. In the end, the fiber was dried in an electrical oven at 60 °C for 2 hours to ensure complete water removal from this fiber. The ratio between resin and its hardener is 99:1.

Table 2. Specimen code for impact and bending test based on varied immersion time and fiber orientation

Specimen code	Immersion duration	Fiber orientation
A1	60 minutes	0° – 90° – 0° – 90°
A2		0° – 90° – 90° – 0°
A3		90° – 0° – 0° – 90°
B1	90 minutes	0° – 90° – 0° – 90°
B2		0° – 90° – 90° – 0°
B3		90° – 0° – 0° – 90°
C1	120 minutes	0° – 90° – 0° – 90°
C2		0° – 90° – 90° – 0°
C3		90° – 0° – 0° – 90°

Hand lay-up technique was used to prepare specimen of impact test in this work. Hand lay-up technique is the simplest process of composite. It can be applied in complex geometry and it needs no complex and expensive machine. Uniformity and process quality of hand lay-up process however may vary in great extent depending on worker skill [18]. Filler can be embedded into matrix through several forms, i.e. flake, fiber and powder [18]-[26]. In this research, each specimen comprises of 4 fiber layers. Fiber sheet was oriented at 0 and 90 degrees toward impact and bending direction with particular layers arrangement (**Table 2**). After sample was prepared by hand lay-up technique, the specimen was pressed at 3 kgf load and then left dried for 4-5 hours. Specimen of bending test was also varied for immersion duration at 60, 90 and 120 minutes. 3 variations of fiber orientation and method for preparation of impact test specimen were applied to prepare specimen of 3-point bending test. Specimens for impact test followed ASTM D256 [27] while specimens for bending test were prepared following ASTM D790 [28].

3. RESULT AND DISCUSSION

3.1 Impact and bending strength

Lay-up orientation of 90°-0°-0°-90° resulted in the lowest impact and bending strength (**Table 3, Figure 2 and Figure 3**). The highest impact strength at 0.294 J/cm² occurs for specimen with fiber orientation of 0°-90°-0°-90° and 90 minutes alkalization duration. For all 3 fiber orientations, alkalization duration at 120 minutes always results in the lowest compared impact strength than that of 60 and 90 minutes alkalization duration. The loss of lignin and other compositions in the fiber due to longer alkalization duration may lead to shrink of wood fiber which decreases the ability of composites to withstand impact load.

In this research, amount and size of wood fiber were not considered. Cui *et al.* [26] reported that higher fraction of sawdust wood fiber in high density polyethylene (HDPE) increases the flexural strength of composites but decreasing the flexurals trength in bending test and impact strength. As comparion, polylactic acid matrix reinforced with posses impact strength between 0.36 to 0.6 J/cm² [14]. These values are more than double compared than values found in this work. Further investigation therefore should be worked out, e.g. searching for the best NaOH concentration applied in alkalization process since in this work, NaOH concentraion was constant at 14 %wt. Manalo *et al.* [21] reported that 6% NaOH content is the optimum level for alkalization of bamboo fiber. It was reported also that the bending strength of composites with treated bamboo fiber is 7% than composites witht untreated bamboo fiber. Wijianto *et al.* [22] reported that optimum alkalization process of banan fiber is for 5% NaOH and 1 hour immersion duration. Alkalization treatment using 15% NaOH decreases elastic modulus, flexural strength and tensile strength of bamboo composites since excessivley high NaOH concentration damages the fiber. Thus, it weaken the strength of interfacial bond between fiber and polymer matrix.

Table 3. Result of impact test and bending test for varied alkalization duration and fiber orientation

Alkalization duration [min]	Impact strength [J/cm ²]	Bending strength [MPa]
Fiber orientation of 0°-90°-0°-90°		
60	0.184	24.04
90	0.294	35.02
120	0.164	48.01
Fiber orientation of 0°-90°-90°-0°		
60	0.210	35.01
90	0.185	31.38
120	0.179	32.75
Fiber orientation of 90°-0°-0°-90°		
60	0.172	16.62
90	0.183	24.11
120	0.165	26.93

Figure 2. Impact strength for varied alkalization duration and fiber orientation

The highest bending strength at 48.01 Mpa occurs for 120 minutes alkalization duration and also for fiber orientation of $0^\circ\text{-}90^\circ\text{-}0^\circ\text{-}90^\circ$. The lowest bending strength 16.62 Mpa occurs for alkalization treatment 60 minutes and fiber orientation of $90^\circ\text{-}0^\circ\text{-}0^\circ\text{-}90^\circ$. Unlike in impact test, alkalization duration for 120 minutes results in relatively higher bending strength. Further investigation needs to be worked out to increase the flexural strength of wood reinforced composites since composites receive load perpendicular to its surface, e.g. as panel in car. Orientation of wood fiber strongly affects the flexural strength of composite resin. The bottom part of composites experience tension stress. As the ability to resist the tension stress occurred at the composite bottom part increases, the flexural strength of composites also increases [23].

In most engineering cases, either metal or non metal materials, bending strength is positively correlated with tensile strength and inversely correlated with elongation at break. This could be the reason for low impact strength as bending strength increases in this work. As the elongation at break decreases, toughness which is area under the tensile test decreases, also decreases. Decreasing toughness is strongly related with decreasing impact strength.

Figure 3. Bending strength for varied alkalization duration and fiber orientation

3.2 Micro analysis

Specimens after impact test for all varied alkalization duration and fiber orientations were analyzed by using micro photographic analysis (**Figure 4** to **Figure 6**). In composites in which good bonding between the matrix and the fiber occurs, the fracture propagate through the fiber. Inversely, fracture only occurs around the fiber without causing any damage to the fiber bad when good bonding between fiber and matrix does not exist (Mokhtar 2007). Void containing air can be observed and this deteriorates mechanical properties of composites.

Meanwhile, area where less filler called rich matrix can be observed as well. In this rich matrix area, no adhesion between fiber and matrix takes place. Thus, mechanical properties at this particular area solely depend on the mechanical properties of polymer matrix. Inversely, area where fewer matrixes called overload can also be observed. In this particular area, mechanical properties of fiber are greatly affected by the mechanical properties of fiber. Fiber pull out in this work exists for 2 cases. The first one is for specimen with alkalization process of 60 minutes for fiber orientation $0^\circ-90^\circ-90^\circ-0^\circ$ while the second one occurs for specimen with alkalization process of 90 minutes for fiber orientation $90^\circ-0^\circ-0^\circ-90^\circ$. This fiber pull out occurs due to no good adhesion between fiber and its matrix. Thus, the crack propagates around the fiber without causing any damage to the fiber.

Figure 4. Micro photos of specimen after impact test with alkalization process of 60 minutes for fiber orientation a) $0^\circ-90^\circ-0^\circ-90^\circ$, b) $0^\circ-90^\circ-90^\circ-0^\circ$ and c) $90^\circ-0^\circ-0^\circ-90^\circ$

Figure 5. Micro photos of specimen after impact test with alkalization process of 90 minutes for fiber orientation a) $0^\circ-90^\circ-0^\circ-90^\circ$, b) $0^\circ-90^\circ-90^\circ-0^\circ$ and c) $90^\circ-0^\circ-0^\circ-90^\circ$

Figure 6. Micro of photos specimen after impact test with alkalization process of 120 minutes for fiber orientation a) $0^\circ-90^\circ-0^\circ-90^\circ$, b) $0^\circ-90^\circ-90^\circ-0^\circ$ and c) $90^\circ-0^\circ-0^\circ-90^\circ$

4. CONCLUSION

The effect of immersion time and orientation on Terap tree bark laminate composites on the impact price is an

increase in impact price strength along with the immersion time until it reaches 90 minutes immersion, then by increasing the time of immersion the impact price decreases until the immersion time is 120 minutes. While the value for the influence of fiber orientation occurs due to the presence of void fluctuations in the specimen. The effect of immersion time and fiber orientation on laminated composite bark fibers of Terap tree on the magnitude of bending stress is an increase in bending stress strength along with soaking time until it reaches a time of 120 minutes. While the value for the influence of fiber orientation occurs due to the presence of void fluctuations in the specimen. Characteristics of crack propagation formed on the fracture of the test results are the fiber cracks which cut the fiber directly, which can be concluded that the adhesion between the fiber (fiber) with the optimal matrix.

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