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THE EFFECT OF FUMIGATION TOWARD THE ENGAGEMENT ABILITY OF KING PINEAPPLE LEAF FIBRE (AGAVE CANTALA ROXB) WITH EPOXY MATRIX

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ABSTRACT

The purpose of this study is to find out the fumigated king pineapple leaf fiber (KPLF) engagement capability behavioural (IFSS) toward the epoxy matrix. The king pineapple leaf fiber fumigation treatment was under a time length of 5, 10, 15, 20 hours with the source of smoke from burning coconut shells and also comparing the KPLF without any fumigation treatment. KPLF without and with fumigation treatment was observed by SEM to determine the ability of the fiber engagement to the epoxy matrix and also for the KPLF surface morphology. The tensile test was conducted to determine interfacial shear strength by embedding a single king pineapple leaf fiber into the epoxy matrix as deep as 1 mm. The test result shows that the fumigation treatment causes the fiber surface becomes coarse, wrinkled, forming uneven grooves in a longitudinal and transverse direction. This condition would improve the KPLF and epoxy matrix engagement ability. The epoxy matrix interface shear stress (IFSS) with the untreated KPLF is a big as 4.48 MPa and for the KPL Ftreated for 15 hours the shear stress is as big as 17.15 MPa.

Keywords: king pineapple leaf fiber, fumigation, interface, shear stress.

1. INTRODUCTION

Natural fibers that have varying physical characteristics can be used as a reinforcing material for composites. King Pineapple (Agave Cantala Roxb) is one of the plants that produce natural fibers that have the potency as a reinforcing material composite. King pineapple plants are found in Indonesia, namely in Tana Toraja, South Sulawesi province. Traditionally the king pineapple leaf fibers have been used since a long time by the local community, as a strap, also woven as corpse wrapper because it is strong and durable when the fibers are fumigated. Given the good economic value and the enormous potential of king pineapple plants then it is attempted to enhance the king pineapple leaf fiber role not only as a traditional material, but improved their function as a raw material for natural fiber composites.

The advantages of using natural fibers as reinforcement composite when compared to synthetic fibers such as glass fibers and carbon is that natural fiber are low in price, low density, easily separated, biodegradable and renewable [1, 2]. Natural cellulose fibers have a hydrophilic nature because it can absorb water from the environment. The high water content can reduce the power of engagement with nature hydrophobic matrix [3]. The main content of natural fibers is cellulose, hemicelluloses, and lignin [4, 5, 6]. Different ways of treatment that has been done to improve the compatibility of natural fibers that is hydrophilic, both physically and chemically. The compatibility between the lingo-cellulosic material and the matrix plays an important role in determining the composites properties.

To improve the natural fibers properties such as surface shape, fiber strength and the interaction between the fiber and the matrix, chemical treatment is one of the methods that need to be considered to eliminate most of hemicelluloses, lignin, wax, and oil. This chemical treatment would change the fiber surface became rough because the reduced of fiber aggregation [3, 7].

Decreasing the lignin amount can reduce the water absorption and the swelling fibers thickness [4]. King pineapple leaf fiber fumigation treatment can reduce the hemicelluloses and lignin content, making the fiber surface becomes rough and grooved, due to the water content reduced and the fiber density increase [8]. The interface fiber engagement capability would affects the composite fiber strength. Interface on a composite is a surface that is formed jointly between the fiber and matrix that form an intermediary bond to transfer load. A good interface can transfer the load from the matrix to the fiber perfectly so that the composite strength could increase [9].

It is caused by the combination of materials making up the composite which have different mechanical properties and chemical properties. To determine the interface strength it is necessary to do a fiber pull-out test. Some of the factors that influence the strength composite natural fibers strength are the fiber form, fiber location, fiber length and the fiber matrix engagement [5]. One to note for the strength or composite toughness is the engagement ability between the fiber surface and matrix [9, 14]. The engagement between the fibers and matrix also influenced by the void or gap formed [5], so that the compatibility between matrix and fibers would excessively determine the composite properties [4]. Some main factors that affecting the bond between the fibers and matrices are the physical adhesion and chemical industries, the mechanical engagement component and the friction factor [9]. The interface nature plays an important role on the composite fiber mechanical behavior analysis. The bond interface characteristic between the fiber and the matrix is

usually studied experimentally by examining some of the physical parameters in the bond various conditions.

The single fiber tensile test and pull-out test has become one of the representative methods and experimental technology has become important in the study of the composite fiber mechanical behavior [9].

Based on the brief description above, the research about king pineapple leaf fiber (Agave CantalaRoxb) with the fumigation treatment was done. The fumigation method used is burning coconut shells in a special drum to produce smoke that contains phenolic compounds, carbonyl and other compounds [10, 11]. After the fumigation treatment to find out the fumigation effect, the fiber treated was then test by looking at the fiber surface morphology and also looking for the fiber and matrix interface engagement ability. The last test is looking for the fiber epoxy matrix shear strength (IFSS) by conducting a fiber pull out test.

2. MATERIALS AND METHODS

The materials used in this study is the king pineapple leaf drawn from the pineapple king fields in Tana Toraja, South Sulawesi Province. The average age of the leaves are about 11 months, with a leaf length of about one meter. These leaves were then soaked in a drum for three weeks to be rotten. Furthermore, fibers that have decayed were then separated from the leaf skin. The fiber is then washed with distilled water to clean the dirt and finally dried at a room temperature of 31° C.

The KPLF was then treated with fumigation in a fumigation box where the smoke obtained from burning coconut shells in another container. This container is connected by pipes to drain the smoke continuously into the fumigation box. The KPLF fumigation process was done at some time variation for 5, 10, 15, and 20 hours. During the fumigation process takes place, the fumigation room temperature is maintained at a temperature of about 45 ° C.

Table-1. King pineapple leaf fiber sample group name.

No.	Fiber sample group	Information
1	KPLF	King pineapple leaf fiber
2	WF	Without fumigation
3	F5H	Five hours fumigation
4	F10H	Ten hours fumigation
5	F15H	Fifteen hours fumigation
6	F20H	Twenty hours fumigation

Fiber with and without fumigation process would follow a series of test. The SEM test is to determine the fiber and matrix engagement, the fiber surface morphology. The pull-out was conducted to determine the fiber and matrix adhesion. The fiber was plant on the matrix and then drawn the fiber with a certain load to obtained the fibers and matrix interfacial shear strength. The fiber and matrix interface strength is greatly affecting the composite material performance. To determine the fiber and matrix interface strength a pull out test is done [13].

The single fiber pull-out test could provide the fiber stress-strain information. The fibers are embedded in a matrix which can then be converted into the interface shear stress. In addition, the beginning of the fiber-matrix de-bonding cause a micro-crack growth to macro failure can be observed [7, 12].

From the single fiber pull out test, it is expected to provide the information on the direct interaction fiber-matrix interface areas. It could be the indication of a micro-mechanics composites stress transfer. Where the better the stress transfer capability, the higher the interface shear strength would be [14, 16].

Figure-1 shows the pull-out test procedure, single fiber was planted on the matrix with a planting depth lo and subjected to the axial tensile load of P. The P load is expected to revoke the fibers embedded in the matrix. It is assumed that the shear stress along the fiber surface is uniform and the force equilibrium occurs. Shear stress (IFSS) between fiber and matrix as shown in Figure-2 which can be calculated using equation:

$$\tau = \frac{P}{\pi d l o} \tag{1}$$

Where P is the maximum load, $d$is the fiber and l_o is the fiber length plant in the matrix.

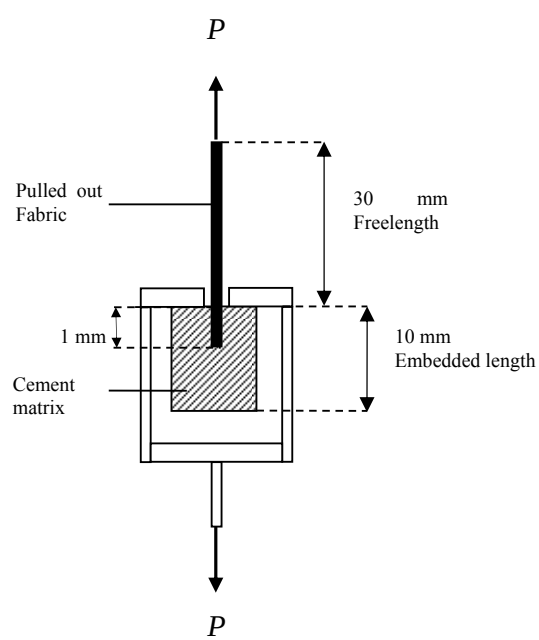


Figure-1. Single fiber Pull out test specimen.

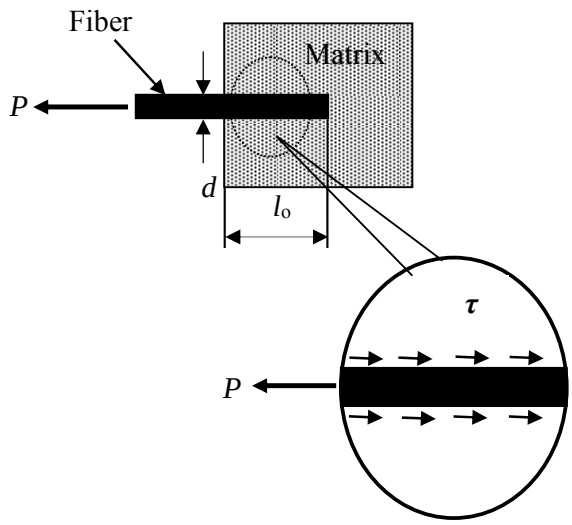
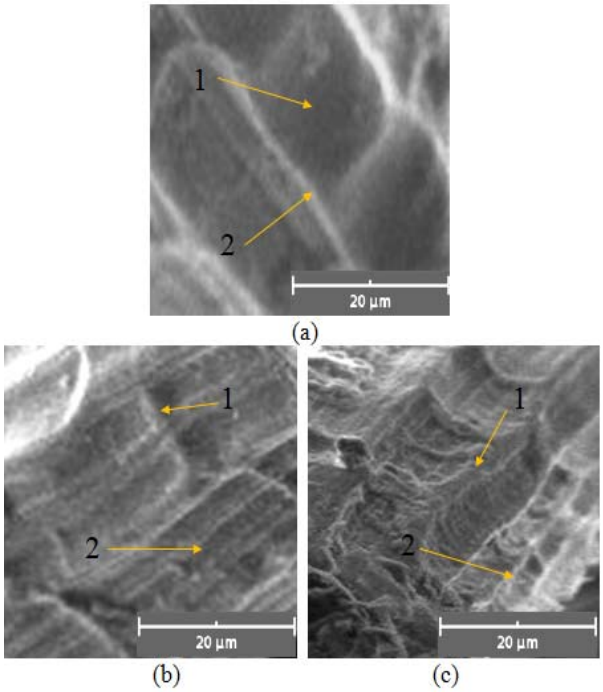


Figure-2. Pull out test mechanism tensile and shear interfacial equilibrium between the fiber surface and matrix.

3. RESULTS AND DISCUSSIONS

Figure-3 (a) shows the KPLF without any fumigation treatment. The fiber surface morphology is smooth (first arrow) and appears an irregular rectangular pattern (arrow 2). However, after a fumigation treatment for 5, 10, 15 and 20 hours, the rectangular patterns periphery changed when compared with the KPLF surface roughness without fumigation. The KPLF surface roughness changes depending on the fumigation time length, as shown in Figure-3 (b), (c), (d) and (e).



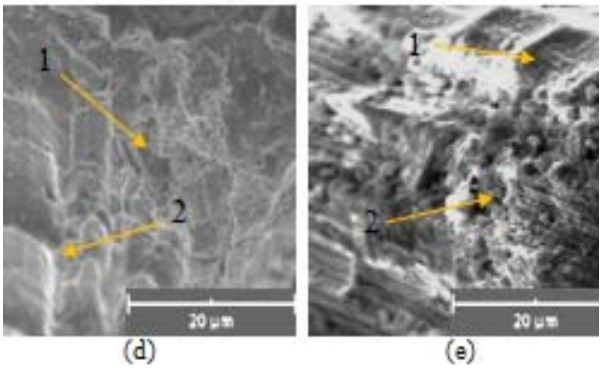


Figure-3. KPLF Surface morphology, SEM result (a).WF, (b). F5H, (c). F10H, (d). F15H, (e). F20H.

Figure-3 (b) shows the KPLF surface morphology with 5 hours fumigation time (F5H) changes the rectangular pattern with a rim protruding, elongated grooves and loks rough (arrow 2), grooved like an trech (arrow 1). But after a 10 hours fumigation time (F10H) the rectangular fringe patterns become irregular (arrow 2). The direction of flow in the pattern does not extend further (arrow 1) as shown in Figure-3 (c).

The surface morphology for KPLF with 15 hours fumigation time has a surface topography as shown in Figure-3 (d), almost the same as fibers fumigated 10 hours, where the longitudinal groove can still be seen on a rectangular pattern and on the groove like on (arrow 1). The pattern does not extend and looks more rough (arrows 2), when compared with the patterns observed on the surface of the fiber with ten hours fumigation time.

Figure-3 (e) shows the KPLF surface morphology with 20 hours fumigation time. It is seen rectangle fringe patterns that are not elongated again and looked rough. Even the rectangle fringe pattern can still be seen but the longitudinal groove is not visible anymore. In this case the groove becomes irregular and rough (arrow 2).

A significant change in the KPLF surface is that it is coarser when compared with the KPLF without fumigation. The pores appear and grooves appear uneven and rough. In addition, because of the fumigation treatment, the pattern edge of the rectangle appears some irregular protrusions, denser and looks bearish. With the change of the pores, grooves and also increase the KPLF surface roughness, it is expected that the matrix would fill the pores and grooves so it would increase the fiber and matrix interface bonding ability.

Because the fiber and matrix interface bonding affect the composite strength, and the bond strength is influenced by the fiber surface morphology fiber roughness [16, 17, 18, 19] and also from matrix structure [20]. The surface of the fiber which is influenced by the fumigation time is associated with the strength of composites reinforced with KPLF. Figure-4 (a) shows the engagement between the matrix and KPLF without fumigation (WF). It is seen that there is a lack of good engagement for smooth fiber surface as shown in Figure-3(a). There is a large gap (arrow 1) and an incomplete

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engagement as shown by arrow 2. But after the KPLF fumigation treated for 5, 10, 15, 20 hours as shown in Figure-4 (b), (c), (d) and (e), every KPLF engagement with the matrix respectively would be better depending on the fumigation time length.

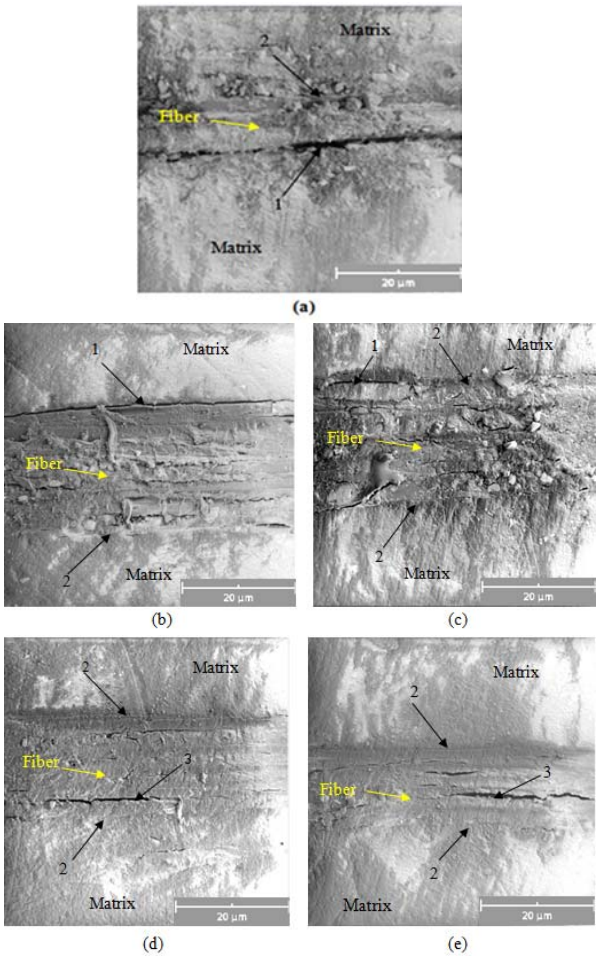

Figure-4. KPLF and matrix interfacial bonding, SEM result (a). WT, (b). F5H, (c). F10H, (d). F15H, (e). F20H.

Figure-4 (b) KPLF with F5H show SDNR engagement with epoxy matrix under conditions which manifest gap is getting smaller as shown by the arrow 1 and arrow 2 shows the engagement better. Figure-4 (c) is KPLF with F10H still visible gap but smaller and not elongated crate indicated by arrows 1 and for the arrow 2 shows the engagement is strong, and is expected as a result of curing, so that the fibers tend to be wetted epoxy and this causes the bonding adhesion be better when compared with F5H. Figure-4. (d) is 15 hours KPLF fumigation, showing a better engagement as indicated by arrows 2, which produces well KPLF and matrix epoxy wetting, so that the KPLF is completely wetted and this would causes a better and stronger KPLF adhesion bonding interface. The strength of the bond adhesion strength is indicated by the mechanical interlock bond. Due to the strong KPLF and matrix epoxy interface engagement a crack is indicated (arrow 3). Likewise in Figure-4 (e), namely KPLF with 20 hours fumigation where the KPLF and epoxy matrix engagement is similar to the KPLF 15 hours treatment. But the KPLF cracks become widening (arrow 3), because the KPLF and matrix epoxy interface adhesion bonding is too strong.

From the pull out test result it is seen that the fumigation treatment would affect the KPLF shearstrength with an epoxy matrix in Figure-5. The KPLF shear strength increase until the 15 hours fumigation time and relatively constant until the 20 hours fumigation time. This happens because the fiber surface is rough and grooved causes the fiber epoxy matrix shear transfer efficiency to be better so that IFSS fiber with epoxy matrix would be relatively constant.

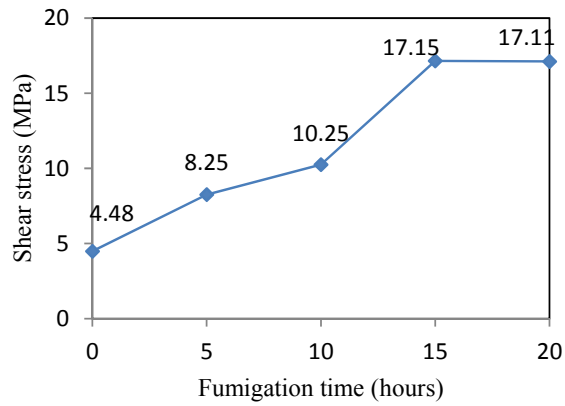

Figure-5. Shear stress vs Fumigation time.

As shown in the previous figure, in which the KPLF fumigation treatment would change the fiber surface morphology. The KPLF surface morphology change is depends on the fumigation duration process. The longer the fumigation time, the rougher the finer surface would as shown in Figure-3.

In Figure-4 (a) in conjunction with Figure-3 (a) indicated that KPLF without fumigation treatment would have a smoother surface when compared with the KPLF fumigated treated.

The smooth surface shows that the fiber without fumigation treatment is still covered by lignin and hemicelluloses, so that the fiber interface engagement is not compatible with epoxy matrix. However, for the KPLF after fumigation would reduce lignin and hemicelluloses, while cellulose content is relatively stable [8]. Due to the long process of fumigation time, hemicelluloses and lignin content would reduce. That is why the fiber surface changes their topography. The topography changes are the formation of pores, grooves and also increase the KPLF surface roughness. This condition is expected to facilitate the matrix to fill the pores and fill the rough groove so that it could enhance the KPLF and matrix connective interface.

The increased of the fiber and epoxy matrix interfacial shear strength occurs due to fumigation

treatment. The highest shear strength (IFSS) is obtained at 17.15 MPa as shown in Figure-5, and the KPLF shearstrength decreased after a 15 hours fumigation time. The shear strength decreases because of the fiber structure damage due to the too long fumigation time.

4. CONCLUSIONS

Based on the previous description of the treatment of the king pineapple leaf fibers it can be concluded that the fumigation treatment: (a). Changing the KPLF surface morphology becomes rough, grooved and opening the pores and rough fringe rectangular pattern which increased the KPLF and epoxy matrix engagement capability. (b) Increase the interface shear stress (IFSS) of KPLF and epoxy matrix as big as 17.15 MPa at a fumigation time of 15 hours.

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