The Effect Of Fumigation Treatment Of King Pineapple Leaf Fiber (Agave Cantala Roxb) On Length Of Fiber Critical Using Epoxy Matrix

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Abstract The purpose of this research was to determine the critical length of the king pineapple leaf fiber (KPLF) due to fumigation treatment with time variations. To determine the critical length is done by pull out test. The pull-out test was conducted to determine the adhesive properties of the KPLF interface with the epoxy matrix by implanting KPLF without and with the fuming treatment into the epoxy matrix then being withdrawn with a certain load and in quantity it can provide tensile stress information which can then be converted into a shear stress fiber with epoxy matrix. The measurement results show the effect of fogging treatment for 15 hours on KPLF, can increase the shear stress of the epoxy matrix interface by 16.75 MPa with a length of 1 mm and a critical length of 4.53 mm.

1. Introduction

Natural fiber has contributed many advantages in the past few years. The advantages of natural fiber as composite material support, when compared to synthetic fiber reinforcement, are low price, low density, easily separated, widely available and renewable, biodegradability and environmental capability [1, 2]. As a result, there is increased new motivation to explore natural fibers that can be applied to the automotive and structural fields that are taking a burden, to replace synthetic fibers.

The problem that arises along with the development of composite material technology is how to utilize materials with sufficient availability of resources that can be regenerated to anticipate material crises especially polymer plastic types where the availability of material sources is influenced by non-renewable petroleum sources [3]. One solution to the problem is to use natural fibers as a plastic polymer blend material to produce composite materials that can be used as widely as possible for engineering applications, both structural and non-structural [4]. Natural fibers that have hydrophilic properties have weakness compatibility with hydrophobic polymer matrices. This weakness can be overcome by providing chemical treatments such as alkali treatment which can remove some lignin, hemicellulose, wax or oil so that the surface of the fiber becomes rough, so there is good compatibility when combined with an epoxy matrix [5, 6]. The binding between the fiber and the matrix is also influenced by voids, the gap formed between the fiber and the matrix. Besides the factors that influence the strength of the natural fiber-reinforced composite to include the shape of the fiber, the location of the fiber, the length of the fiber, the binding of the fiber to the matrix [6].
The fiber interface bond is very influential on the strength of the fiber reinforced composite. The interface on the composite is a surface formed jointly form the bond between the fiber and the matrix that forms the intermediate bonds needed in load transfer. Several main factors affect the bond between the fiber and the matrix such as (i) physical and chemical adhesion, (ii) binding of mechanical components, and (iii) friction [7]. A good interface can move loads from the matrix to the fiber perfectly to increase the strength of the composite. One thing that needs to be considered to get the strength or tenacity of the composite is the nature of the ability to bond the fiber interface with the matrix [7, 8].

The method to determine the strength of the fiber interface with the matrix is taken, among others, through the pullout test. A single fiber pull-out test is expected to provide information about the direct interaction of the fiber interface region with the matrix and is an indicator of composite voltage-transfer micromechanics where the better voltage transfer capability results in high interface shear strength [6, 9]. Single fiber pulls out test has become one of the representative methods and has become an important experimental technology in studying the mechanical behaviour of fiber-reinforced composites [6, 7, 10]. Interface properties play an important role in analyzing the mechanical behaviour of composites with natural fiber reinforcement. The characteristics of natural fibers are usually examined experimentally by examining several parameters, namely physical, chemical and mechanical properties of natural fibers which have a lot of available sources in Indonesia and one of them is Raja pineapple leaf fiber, for composite reinforcement material [11].

Based on the description above, in general, the surface treatment of natural fibers uses alkali and other chemicals, and as an alternative material for the treatment of fiber fumigation by using coconut shell smoke. In the fumigation process occurs the withdrawal of water and the deposition of various chemical compounds derived from coconut shell smoke so that it can change the chemical, physical properties of the product smoked due to carbonyl, phenol and acetic acid compounds [13, 14]. Fumigation can also reduce lignin and hemicellulose due to acetic acid because acetic acid can break lignin chain bonds and also penetrate the hemicellulose chain bonds so that the surface of the fiber becomes rough [13, 15, 16], because lignin and hemicellulose are aortic while cellulose is a chemical element that is of a chemical nature crystalline [14, 17, 18].

Fumigation plays a role in producing surface topographic changes, increasing the mechanical strength of KPLF [14, 19] and a series of tests are carried out to reveal the effect of fumigation on the shear strength of KPLF with an epoxy matrix with pull out test method and critical length of KPLF without and without fumigation treatment.

2. Research Method

2.1. Fiber Material
The research material is king pineapple leaf fiber (KPLF) obtained from Tana Toraja Regency in South Sulawesi, Indonesia. Fiber is removed from the decomposed leaf flesh mechanically and KPLF length with a range of 0.9-1m after being soaked in fresh water for three weeks. Furthermore, KPLF was cleaned of impurities using distilled water, then dried at room temperature for 1 hour after which it was grouped to be treated with fogging. The chemical content of KPLF is 55.8% cellulose, 20.27% hemicellulose, 7.66% lignin, 13.6% extractive material and moisture content 5.39 - 5.88% [14].

2.2. Fumigation Treatment
The KPLF fumigation treatment was carried out in the fumigation box where smoke was obtained by burning coconut shells in a container connected to a pipe to drain smoke continuously into the fumigation box. The smoke temperature in the KPLF fumigation chamber averages 45 °C during the KPLF fogging process for 5, 10, 15, and 20 hours, respectively. [16] Every KPLF sample without and with fogging was given a notation Without fumigation (WF), Five hours fumigation (F5H), Ten hours fumigation (F10H), Fifteen hours fumigation (F15H), Twenty hours fumigation (F20H).
2.3. Epoxy Resin Material
The epoxy resin used is Diglycidyl Ether of Bisphenol-A (DGEBA), the reaction between bisphenol-A and epichlorohydrin mixed with methyl ethyl katon peroxide (MEKPO) catalyst which is a clear liquid.

2.4. Pull Out Testing
Figure 1 (a) shows the pull-out test procedure where a single fiber is planted into a matrix with a depth of planting with an axial tensile load of $F$. Load $F$ is expected to be able to pull out the fiber embedded into the matrix assuming a force balance occurs so that shear stresses along uniform fiber surface. The shear stress ($\tau_y$) between the fiber and the matrix like Figure 1 (b) can be calculated using the equation:

$$\tau_y = \frac{F}{\pi d_o l_o}$$

(1)

![Figure 1. Mechanism of pull-out test (a) Single fiber pull-out test specimen (b) Equivalent of interfacial tensile and shear forces between the surface of the fiber and the epoxy matrix [16]](image-url)

The critical length of the fiber is a good indicator of the ability to bond the fiber interface with the epoxy matrix to carry the load between the two elements, assuming the shear stress experienced by the fiber is the same at each point, so from the Kelly-Tyson model the equation 2 is obtained as follows :

$$l_x = \frac{\sigma_{f,max} d_o}{2 \tau_y}$$

(2)

Where :
- $l_x$ = critical length of a single fiber (mm)
- $d_o$ = diameter of the fiber embedded in the epoxy matrix (mm)
- $\tau_y$ = shear stress (MPa)
- $\sigma_{f,max}$ = Maximum tensile stress (MPa)
3. Results and Discussion

Figure 1 is the KPLF color surface without and with fogging treatment. The duration of KPLF fumigation treatment affected the change in KPLF surface color due to carbonyl compounds [13, 14], as follows.

![Figure 2. Color KPLF Vs Fogging time](image)

Figure 2 (a, b) is the result of SEM photo of KPLF section, without and with fumigation treatment. The WF cross section appears smooth and closed grooves as in Figure 2 (a), while the surface of the KPLF after the fumigation treatment appears rough grooves as in Figure 2 (b), as follows.

![Figure 3. SEM photo of KPLF surface, (a). WF, (b)](image)

The flow on the surface of the KPLF which was originally occupied by water molecules and covered by lignin, with fuming there occurs a chemical reaction so that the cellular chain of the KPLF surface is better, because the water content in the KPLF decreases [14, 16], so the KPLF diameter diameter and the specific gravity increases as in figure 4, due to the presence of carbonil contained in coconut shell smoke [14, 20, 21, 22], so that the mechanical strength of KPLF increases [14]. The grooves formed can facilitate the adhesion of the epoxy matrix to the surface of the KPLF so that a compatible bond occurs, and also facilitate the base of the KPLF. The fiber surface condition is related to the binding of the epoxy matrix interface with the KPLF which is affected by the time of fogging.
Figure 3. is the results of a single pineapple king fiber pull out test and the effect of fogging on the shear strength between the KPLF and the epoxy matrix when compared to the KPLF without fumigation. The shear strength of WF was 4.45 MPa and increased to 16.75 MPa at F15H and then relatively decreased until F20H fumigation was as follows.

![Figure 4](image-url)  
**Figure 4.** KPLF shear stress Vs. Fumigation time

In Figure 4, the effect of fumigation on specific gravity, fiber diameter and critical length of KPLF and appears to increase in specific gravity and KPLF diameter decreases and the critical length of WF 3.42 mm and increases to 4.53 mm at F15H and relatively decreases at F20H as follows.

![Figure 5](image-url)  
**Figure 5.** KPLF Specific gravity, Fiber diameter, Critical length Vs. Fumigation time

The effect of fumigation which has an impact on changes in epoxy matrix wetting as an adhesive medium that has the ability to coat the surface area of the KPLF [12, 14]. The binding of the KPLF interface adhesion with the epoxy matrix is better and stronger because the surface of the KPLF is grooved and rough due to loss of some of the lignin and hemicellulose elements, due to fogging [14,
The strength of the adhesion bond is due to the penetration of the epoxy matrix into the grooves and fissures on the surface of the KPLF, Figure 2b, resulting in a mechanical interlock bond between the KPLF and a compatible epoxy matrix characterized by increased shear strength and optimal critical length to F15H and critical length and strength KPLF shear is relatively decreased at F20H.

4. CONCLUSION

Based on the previous description of the critical length of KPLF with a pullout test due to the influence of SDNR fumigation treatment, it can be concluded that:

1. The duration of KPLF fogging treatment affected the critical length of KPLF, and the highest was obtained at F15H of 4.53 mm with a planting length of 1 mm.
2. The ability to interface or compatibility of KPLF with the epoxy matrix is getting better which is indicated by the interfacial shear stress of KPLF without smoking at 4.45 MPa and increased to 16.75 MPa at F15H.

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