# Mechanical Properties of Pineapple Fiber and Unidirectional Pineapple Fiber Reinforced Polyester Composite

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Nowadays, a lot of preliminary researches on natural fibre composite were carried out to replace composite reinforced by synthetic fibre. The main advantages of this natural fibre composite are the low cost of the raw fibre, environmental friendly, recyclable and high ratio of modulus and density. Pineapple fibre is available as agriculture waste. The tensile properties of pineapple fibre were carried out in order to know the possibility of using this fibre as reinforcement. The pineapple fibre shows an adequate strength of 194.12 MPa. Natural fibre composite with pineapple fibre as a reinforcement in polymer matrix was investigated. The pineapple fibre reinforced polyester composite was produced using a simple technique called hand lay-up technique. To maintain a low cost, the composite was produced without compatibilizer. Tensile test were carried out to investigate the mechanical properties of the composite. The result shows that the tensile strength increases with the particle loading. The scanning electron micrograph shows intermediate compatibility between particle and polyester matrix.

**Keywords**: Natural Composites, Polyester, Hand lay-up, Pineapple Fiber, Mechanical properties

## Introduction

Recently, the natural fiber reinforced composite is frequently being investigated and some application are also explored. The advantages of this renewable fiber are its low cost couple with the adequate strength, renewable and environmental friendly. The researches on natural fiber composite has been identified some problems in gaining the optimum properties of this renewable fiber as reinforce in polymer composite. It includes high variability of fiber dimension, the compatibility between fiber and matrix, high moisture absorption and thermal degradation.

Research by shusheel et.al. was about the reduction of hydrophilic component in fiber. It was found that to determine the strength of the fiber itself. Every single fiber was composed of fibrils held together by noncellulosic substances, such as lignin and pectin. The cellulose fibers had the elastic modulus of 40 GPa and can be further increases to 70 GPa by subdivided into micro fibril. These microfibril sizes was 10-30 nm and were made up of 30-100 cellulose molecules chains conformation and provide mechanical strength to the fiber. Tensile strength of flax was found to be dependent with the length while the tensile strength of pineapple fiber was found to have a little dependence to the fiber length.

There are some investigations on pineapple fiber composite. The treatment of Pineapple leaf fiber enhances the mechanical properties of polycarbonate-based composites. However, the thermal stability decreases as the loading of kenaf increases (Wanjun Liu et.al.).

Pre-treatment of pineapple leaf fiber (PALF) by Threepopnatkul et.al. was done using NaOH and further treatment of PALF surface was done using two kinds of silane, PALF/Z-6011 and PALF/Z-6030. The silane Z-6011 is more polar than the silane Z-6030. FTIR spectrums have confirmed the chemical reaction occurs between silane and cellulose backbone, especially for PALF/Z-6011. The PALF was then being used to reinforce Polycarbonat composite (PALF/PC). SEM micrograph on the composites had shown smooth surface of PALF/NaOH, some matrix adhere on the surface of PALF/Z-6011 and a gap between matrix and PALF/Z-6030. Elastic modulus of NaOH pre-treated composite without silane-treatment showed the increase of modulus with PALF content. Tensile strength for all composites was found to slightly increase with the PALF content except uncertainty was observed on PALF/Z-6030 composite. However the elongation at break, impact strength and thermal stability was found to decrease with PALF content except for impact strength of PLF/Z-6011.

Short pineapple leaf fiber (PALF) was treated with Sodium hydroxide (NaOH) and benzoyl peroxide (BPO) by Natinee et.al. This PALF was then reinforced natural rubber (NR). From the stress-strain curve, the highest loading of PALF fiber is observed to give a high stress at a given level of strain. It was found that all surface modifications enhanced adhesion and was lead to higher tensile properties of treated fiber composite compare with untreated composite. However the enhancement was lower than neat natural rubber. The PALF-NR composites also exhibited better resistance to aging than its gum vulcanizate, especially when combined with the treated fibers. Most of the composite mention above use compatibilizer to enhance matrix-fiber adhesion. However, it increases the cost of the composite.

In this paper, the PALF fiber from the agriculture waste is used to reinforce UP without addition of compatibilizer. A simple technique namely hand lay-up is used in preparing the PALF/UP composite. The tensile test is conducted for PALF fiber and the PALF/UP. The flexural test is also carried out for PALF/UP composite. The SEM micrograph is conducted for PALF fiber and PALF/UP.

## Materials and Methods

### Materials

The matrix was unsaturated polyester resin, Yukalac 157 BQTN-EX. The specific gravity of cured polyester was 1.215 at 25ºC and the viscosity number was 4.5-5.0 poise (Anonim). The polymer matrix was received in liquid form. The catalyst for the resin was Metil etil keton and peroksida (MEXPO).

The pineapple leaf (PALF), a kind of *smooth cayenne*, was a waste of food industry in Lampung Province, Indonesia. Firstly, the pineapple leaf was compressed to push the water out. Then the fiber was extracted by brushing out the fiber from the fiber bundle. The fiber was washed and immersed in distilled water of 70ºC for 92 hours. The fiber then was washed using ethanol. The fiber was drying for 24 hours at temperature 70ºC in the furnace and then immersed in 5% NaOH solution for 24 hours. After cleaning the remained NaOH in the fiber with distilled water, the fiber was dried at room temperature for 72 hours. The Fiber length and diameter were measured with an optical microscope (SEM).

### Preparation of the Composite

The loadings of the PALF fiber were 10%, 20% and 30%. Composite sheet was made by hand lay-up technique. Unsaturated polyester was first mixed with 1% MEXPO. The mirror glaze was coated onto the mould surface. The mixture was then poured into the glass mould. The PALF fiber is arranged longitudinally over the layer of polyester mixture. The same process was repeated until three layers of polyester and PALF is applied. The load than introduce into the mould to give the pressure on the composite. After 24 hours, the composite was taking out from the mould and store in the furnace for curing at 70ºC for 4 hours. Cured composite was then cut into tensile specimen.

### Tensile Test

Tensile test were carried out to investigate the mechanical properties of PALF fiber and the associate composite. The tensile test of the fiber was conducted according to ASTM D638-I. The tensile test was carried out using universal testing machine, Shimadzu, with the crosshead speed of 5 mm/minute. The appropriate condition was introduced to the specimen before the test at temperature of 23±2ºC and relative humidity of 50±5%. The temperature and humidity during the test were 23.4 ºC and 61%, respectively. Scanning micrograph of the composite was carried out using SEM JEOL JSM-6390A after covering the specimen surface with the JEOL JFC-1600 auto fine coater.

## Result and Discussion

### Tensile strength of PALF fiber

PALF fibers were found to vary in size of 120-240 µm in diameter as shown in figure 1. Tensile strength, elastic modulus and strain of the fiber are 55-110 MPa, 3.65-6.27 GPa and 2.16-4.14% respectively.

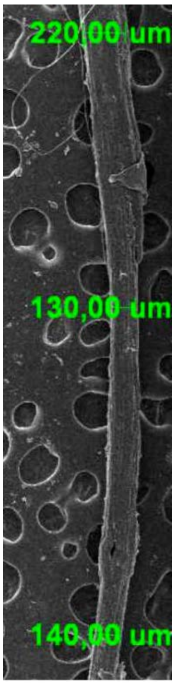


**Figure 1.** Diameter of the PALF fiber

Figures 2-3 shows the fiber fracture under tensile load. The PALF fiber cross section exhibited smooth surface as shown in figure 2. Research by Gunawan et.al. found that there were voids in cross section of EFB fiber. These voids increased in size as the fiber diameter increased. Larger voids have been found to decrease fiber strength (Gunawan). The void in PALF fiber in Figure 2 might be invisible since the fiber diameter is decreases because of tensile load applied. In figure 2-3, the fracture profile of fiber shows a ductile behavior of fiber.

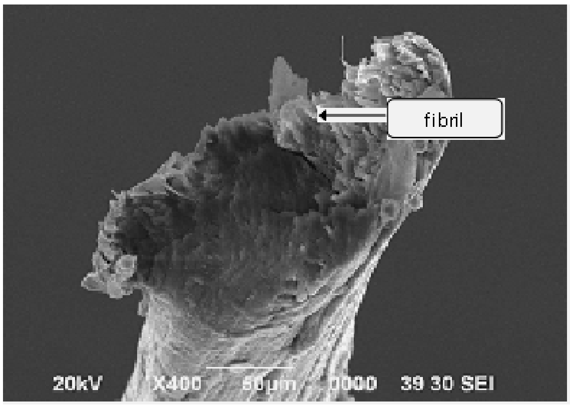


**Figure 2.** Morphologi of fiber cross section

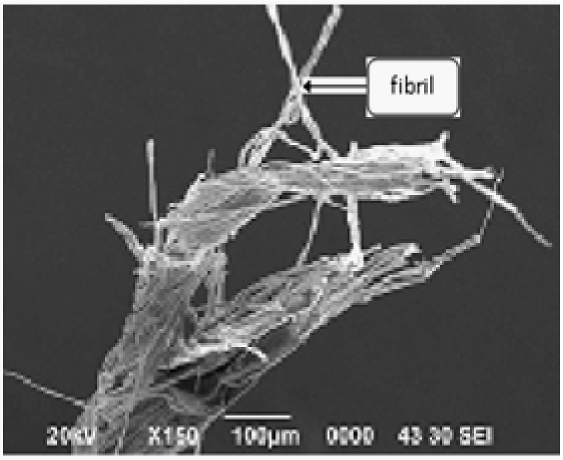


**Figure 3.** Fracture of PALF fiber under tensile load

**Compatibility of Polymer Matrix and CS Particle**

Figure 4 shows SEM images of the cross section of fractured UP/PALF composite. The compatibility between UP and PALF fiber were found low since there was a gap between matrix and the fiber.

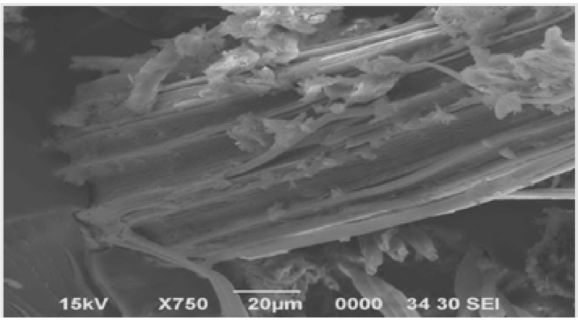


**Figure 4.** SEM micrograph of Compatibility PALF Fiber with UP Matrix

Tensile load is introduced parallel to the fiber. Stress-strain curve for pure polyester and UP/PALF 30%wt are shown in figures 5-6. In comparison between those figures, the stress-strain curve of pure polyester shows a brittle behavior of pure polyester whereas UP/PALF30% composite shows a ductile behavior.

In figure 7, the elastic modulus of UP/PALF fiber increased with the fiber content. The fiber restricted the matrix yielding which lead to the increase of composite elastic modulus. The tensile strength of UP/PALF fiber was found to increase up to 83% with increasing PALF fiber loading as shown in figure 8.

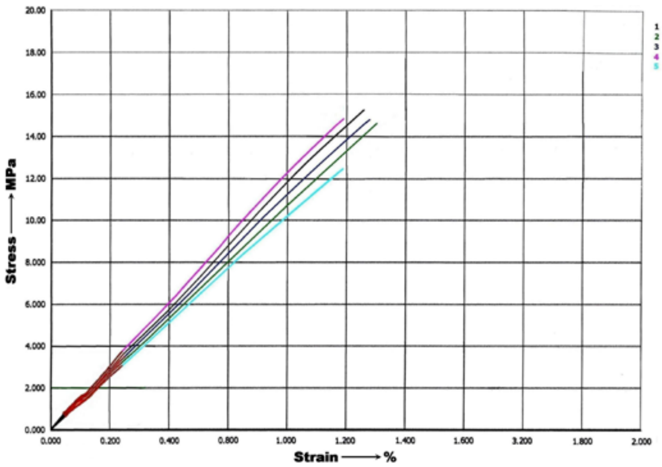


**Figure 5.** Stress-strain curve of pure poliester

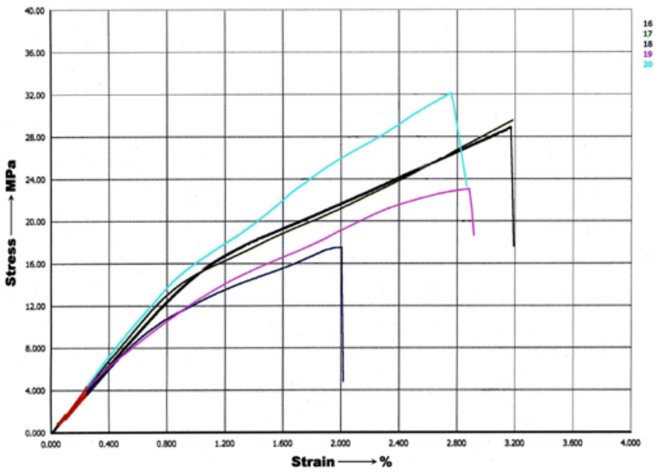


**Figure 6.** Stress-strain curve of UP/PALF30%wt composite

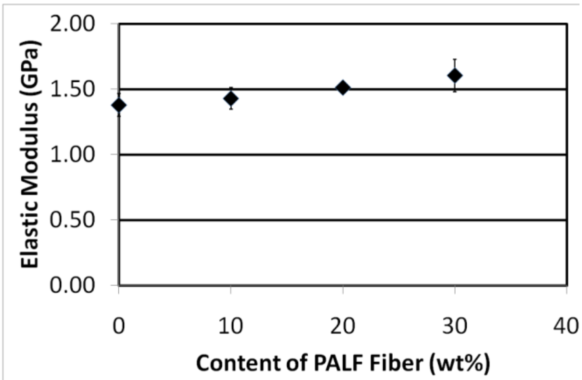


**Figure 7.** Elastic modulus as a function of PALF fiber

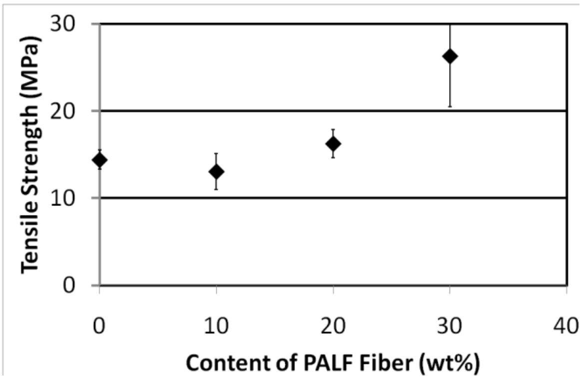


**Figure 8.** Tensile Strength as a Function of PALF

As previously mentioned, the composite showed a low compatibility with the poliester matrix. Based on this, the transfer of stress into the particle or fiber might not achieve the optimum value. However, other factors also affect strength such as fiber length, fiber distribution and fiber population. The factor of fiber length can be neglected here since this composite is unidirectional composite with continuous fiber across the tensile specimen. As shown in figures 9-11, the uniform fiber distribution and population might result in high strength of UP/PALF composite.

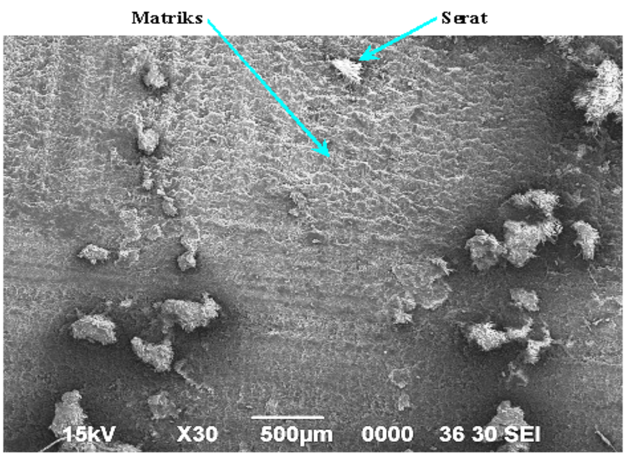


**Figure** 9. SEM micrograph of PALF fiber embedded in polyester matrix for 10 wt%

The strain at failure of UP/PALF composite increased up to 128% as the percentage of the PALF fiber loading increased as shown in Figure 12. As mention before, PALF fiber show a ductile fracture, ductile fiber with adequate matrix-fiber bonding enhances the composite failure strain.

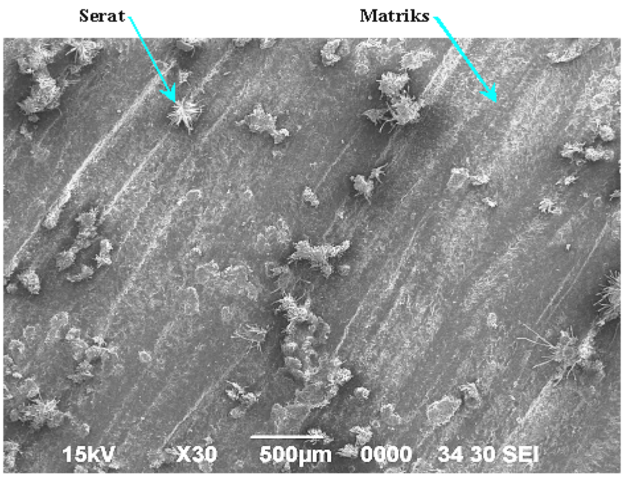


**Figure 10.** SEM micrograph of PALF fiber embedded in polyester matrix for 20 wt%

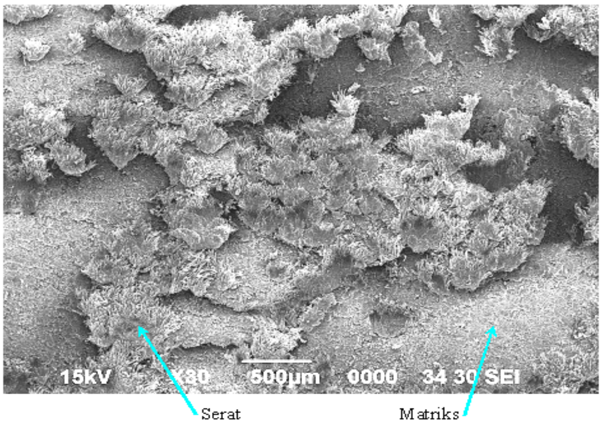


**Figure 11.** SEM micrograph of PALF fiber embedded in polyester matrix for 30 wt%

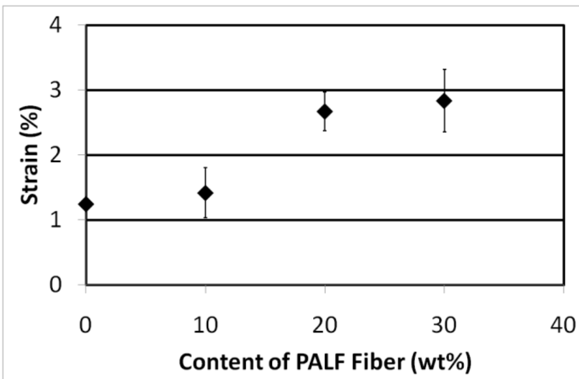


**Figure 12.** Strain as a Function of PALF Fiber

## Conclusions

Pineapple fiber (PALF) was used to increases the tensile properties of unidirectional UP/PALF composite. The tensile properties of the composite such as elastic modulus and tensile strength were increase with the fiber content. Despite the low adhesion between fiber and matrix, the load supposed to be effectively carried by the fiber effectively since the fiber length was long. PALF fiber shows a ductile behaviour which lead to the enhancement of the strain to failure of UP/PALF composite. It is suggested that an enhancement of bonding between fiber and matrix will further increases the strength of composite.

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