Static analysis on Malaysian Yankee’s pineapple leaf fiber/epoxy composite

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Abstract. The static analysis on pineapple leaf fibre (PALF) reinforced epoxy composites was carried out in this study. The effect of fiber alignment in X and Y axis were studied while maintaining total fiber loading of 10% by weight. The bending and compression strength were analyzed by performing flexural and compression test. The composite properties was strongly influence by the fiber orientation where Y axis shows improvement about 97% in bending and 5.3% in compressive strength compared to neat epoxy. However, as for X orientation bending test shows lower bending strength compared to neat epoxy but improve 4% in compressive strength. It can be concluded that the fiber alignment in Y-direction is more suitable to be utilized for automotive interior or household applications that demand high strength properties.

1. Introduction
In 2016, natural fiber composite market size was valued at USD 4.46 billion worldwide. It is expected to grow 11.8 % of compound annual growth rate (CAGR) from 2016-2024 due awareness on environment pollution and high demand for light weight component from automotive industry [1]. An example of automotive interior component produced from natural materials is door panels that are made from flax/sisal reinforce thermoset resin [2]. Among all natural fibers, pineapple leaf fibers (PALF) is the best candidate to be used as reinforcement in composite as it shows superior mechanical strength due to high cellulose content [3]. In Malaysia alone, there are more than 10 varieties of pineapple namely Josapine, Sarawak, Moris Gajah, Yankee, Maspine, N36, etc which proves that there are abundant of leaf waste that could be convert into sustainable materials. Previous study on Josapine’s PALF on 30mm and 200mm fiber length reinforce composite shows that longer fiber had higher bending strength [4]. Fiber length of 2.4 and 6 cm and loading of 50, 60 and 70% of Josapine’s PALF reinforce starch composites properties had been studied in term of tensile, flexural and hardness [5]. Extend to this study, the author had varied the starch (75, 100 and 250 µm) size reinforce with three different cultivars namely Josapine, Moris Gajah and Sarawak [6]. On top of that, in different studies evaluation of 10% fiber (Moris Gajah, Maspine, Josapine and N36) loading reinforced Polylactic acid composites had been done on tensile and flexural properties [7]. Besides, Josapine’s
PALF reinforced polypropylene composites with fixed 100mm length and different weight percentage (30, 40, 50, 60, 70%wt) had investigated its tensile and hardness strength [8]. Author [9] concluded that PALF had the credibility to be utilized in biofuel and bio composites. However, there are none study on Yankee’s PALF natural fiber composite. Previous studies had shown that different variety of plants yield different properties. However, the potentials of the Yankee Pineapple variety in the composite industry remains untapped to date. No studies had been carried out on the PALF natural fiber composite drawn from the Yankee variant. This study is aimed at investigating the mechanical properties of the leaf fiber of the new Malaysian pineapple variety in composite applications.

2. Material Preparation
The natural fiber employed in this study was pineapple leaf’s fiber (PALF) of Yankee variety collected at Teluk Panglima Garang, Selangor, Malaysia. The pineapple leaf is collected after the pineapple harvesting process and the age of the collected leaf is aged around 1-2 years old. The collected leaf was then extracted mechanically at Universiti Tun Hussein Onn and the extracted fiber was called as PALF. The PALF are then sun dried for 2 days to remove its water content. The dried PALF are comb and stored in closed compartment to prevent absorption of water and contamination from surrounding such as dust. Based on chemical composition analysis on this fiber, it was found out there were cellulose (47.74%), hemicellulose (15.98%) and lignin (2.44%). The natural fiber composite was fabricated by aligned the fiber continuously in one direction as shown in Figure 1. The total fiber loading reinforcing in the matrix and thickness was fixed at 10% by weight and 4mm respectively. A pure epoxy plate was also fabricated as control samples. Before the fabrication process start, the surface of mould was wax for ease of removal. The ratio used for epoxy to hardener was 3:1 and was stir uniformly for 5 min which then was used to impregnated with the fiber in a mould. The mould was cured by using hot press at 120° for 10minutes with a constant 250 bars. Directly after hot press continue with cold press for 5 minutes with constant 250 bars. The composite was then cut according to X and Y fiber alignment as shown in the Figure 1. Compression test was carried as per ASTM D695 with dimension 12.7 x 12.7 x 4 mm and the cross speed 1.3mm/min. Flexural test was carried out according to ASTM D7264 with standard span to thickness ratio of 32:1, width 13 mm through three-point bending test using Universal Testing Machine (UTM). The rate of displacement was set at 2mm/min. Morphology of tested composite sample were studied using scanning electron microscope (SEM, Hitachi S3400N). The samples were sputter coated with gold for better visualization.

3. Results and Discussions

3.1 Flexural Analysis
Figure 2 shows flexural strength and flexural modulus for all the tested samples.
Composite made from fibre in Y-direction shows 93.7% improvement in flexural maximum stress compared to neat epoxy. This shows that, PALF helps in transferring the load more effectively in Y-axis throughout the composite, thus contribute to the total strength of the composite. Besides, the Y-direction fiber composite shows the highest modulus indicate that it had the highest stiffness. However, composite made from PALF in X-direction experience reduction 28.3% in strength to neat epoxy maybe due to short distance stress distribution throughout the fiber end causing it to fail at lower stress. Other reason could be contributed by low interfacial bonding between PALF as discussed in morphology analysis section. The results of this research show that composite made from Y-direction fiber alignment are comparable with other PALF composite as per Table 1 even though, the fiber loading used is 10%. This shows that, the fiber alignment plays a huge role in contributing to the overall composite strength. By considering both mentioned parameters in a composite fabrication, fiber loading percentage can be optimized so that it is possible to achieve higher natural fiber composite strength compared to synthetic composite.

| Fiber condition                              | Layering method | Matrix   | Flexural strength (MPa) | Reference  |
|----------------------------------------------|-----------------|----------|-------------------------|------------|
| 10%; continuous fiber Yankee’s PALF          | Y-direction     | Epoxy    | 68.13                   | Current research |
| 30%; length 30mm PALF(P)                     | PPPPPP          | Polyester| 107                     | [10]        |
| 40%; length 0.8-1mm Indonesia PALF           | Short fiber     | Phenolic | 65                      | [11]        |
| 30%; length 30mm Josapine’s PALF             | Short fiber     | PLA      | 32                      | [4]         |
| 30%; length 200mm Josapine’s PALF            | Long Fiber      | PLA      | 52                      | [4]         |

3.2 Compression Analysis

![Compression Test](image)

**Figure 3.** Compressive strength of composite.
Figure 3 shows that by adding 10% of Yankees PALF into the neat epoxy composite, helps to improve the compressive strength up to 5.3% regardless of the fiber orientation. It also shows that the fiber orientation in the matrix plays important role as it contribute to the matrix strength as well. Composite made from fiber in Y direction shows 1.3% higher compressive strength compared to composite made from fiber in X direction as shown in Figure 3. However, even though Y-direction fiber composite had the highest compressive strength, the stiffness of the composite reduced compared to neat epoxy. Previous study [12] shows that composite made from long pineapple fiber hybridised with woven glass fiber (G/PY/PX/PY/G) epoxy composites had compressive strength of 64.4 MPa. The different of compressive strength compared to composite made from fiber in Y direction in current study was only 2% lower. This shows that, the compressive strength is comparable even the current study did not do any hybridisation process and without using any synthetic fiber. This shows that having right orientation according to the load direction will help the stress distribution more effectively hence increasing the strength of the composite.

3.3 Morphology Analysis
The morphology of fails flexural testing specimen were taken randomly and studied using SEM. From the cross-section surface, Figure 4 shows there are small gap between the fiber-matrix (which as shown by the arrow) and fiber pull out. This mean there are some part of fiber that are not properly merge with the matrix or it is not strong enough to hold the load causing it to shear hence creating the gap. The gap shows there were limited bonding between fiber and matrix as fiber had hydrophilic nature properties while the matrix had hydrophobic properties resulting to poor interfacial bonding [13-17].

![Figure 4. Cross section crack from flexural test.](image)

**Conclusion**
Generally, the addition of PALF in epoxy matrix help increasing the composite strength. The orientation of fiber in matrix plays an important role in absorbing the external stress. Composite made from Y-direction fiber orientation were the best configuration in this study where the maximum bending and compressive stress that it can hold before it fails were 68.13 MPa and 63.3 MPa respectively. From morphology analysis by SEM, it can be concluded that the interfacial bonding fiber-matrix play a vital role in contributing to the composite mechanical properties.

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