Mechanical and morphology of interwoven Kenaf/PALF hybrid composites at different fibre ratio

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Abstract. As the extension to the research involving woven and natural fibre hybrid composites, this study characterise the mechanical properties of natural fibre hybrid composites with different fibre ratio. Plain weaved kenaf/PALF composites with fibre weight ratio of 10/10, 15/15 and 20/20 are fabricated via the hand lay up technique using epoxy as the matrix. Tensile and flexural test are performed according to ASTM D3039 and ASTM D790 standards, respectively. Morphological structure of the fracture specimens were examine using the Scanning Electron Microscope (SEM). As a result, the 15/15 fibre ratio composite had the highest tensile and flexural strength. Addition of kenaf fibre improve the mechanical properties of the composites and increase the potential of PALF fibre as filler for future natural fibre applications.

1. Introduction
The alloys legacy have been dominated the automotive industry and as time passed, scientist were requested to develop a lighter material with similar or superior mechanical properties as the existing material. This forms a part of an efforts to achieve the 2025 global vision of reducing fuel consumption by automobiles and aerospace vehicles by at least 75%. Composites have been analyzed as suitable materials in this regard [1].

Generally, composite materials consist of two phases, a matrix and a filler or reinforcement. A matrix is a material that performs as sticking medium for reinforcements [2]. The matrix supports and bonds reinforcement together and conveys the applied load to the reinforcement. Furthermore, the matrix keeps filler in their position, orientation and protect the composite from external attack. Fillers or reinforcements are the loadings bearing components of composites. They offer strength, solidity and supports composite in bearing structural loads to increase the mechanical properties of the neat resin system [1]. Synthetic filler that commonly used for composite are Kevlar, glass, alumina, polyester and nylon. However, due to the environment and cost issue, natural fibre such as cotton, pineapple leaf, kenaf, jute, bagasse and bamboo are preferable as filler for composites.

The use of natural fibres as an alternative to synthetic fibres getting high interest due to sustainability and environmental issues. It is believed that the source of petroleum based products are limited, uncertain and not fully biodegradable. Therefore, a substitute material; which is cheap, readily available, renewable and at the same time have relatively high strength and stiffness is required. Their low densities values allow producing composites that combine good mechanical properties with a low specific mass, biodegradability and absence of health hazards [2].
Yearly, about 30 million tonnes of natural fibres are produced worldwide and been used in varies of industries such as clothing, packaging, paper industry, automobiles, building materials, and sports equipment [3]. Low cost natural fibre can be reused and much safer to the environment when it is burned for disposal, compared to the synthetic fibres [4].

From the previous study, the common hybrid combination found is the natural fibre been layered between the synthetic fibres. Since there were less reported work about the hybrid composites that solely consist of natural fibre, this paper investigate the mechanical and morphology of interwoven kenaf/PALF composites at different fibre ratio. Through this study, the waste from the pineapple cultivation activity could be converted into something beneficial for our future generation and contribute new findings to the natural fibre research community.

2. Experimental Method

2.1. Material Preparation

For the fabrication of the woven fabric, kenaf and pineapple leaf fibre (PALF) yarns supplied by Innovative Pultrusion Sdn. Bhd. are used. The EpoxAmite 100 series resin, supplied by Castmech Technologies Sdn. Bhd is selected as the polymer matrix, and it is mixed with a hardener in a ratio 100:28.4 by weight. Detailed constituents and mechanical properties of materials are as listed in table 1 and 2.

| Reinforcement | Cellulose (wt%) | Cell wall thickness (um) | Lignin (wt%) | Microfibrillar angle (°) |
|---------------|-----------------|--------------------------|--------------|-------------------------|
| Kenaf         | 45-57           | 4.2                      | 9            | 15                      |
| PALF          | 70-82           | 8.3                      | 12           | 14                      |

| Material | Tensile Strength (MPa) | Elastic Modulus (GPa) | Elongation at break (%) | Density (g/ cm³) |
|----------|------------------------|-----------------------|-------------------------|------------------|
| Kenaf    | 427                    | 53                    | 1.6                     | 1.3              |
| PALF     | 170-413                | 18.934-34.5           | 1.6                     | 1.526            |
| Epoxy    | 55                     | 1.75                  | 6                       | 1.1              |

2.2. Fabrication of interwoven kenaf/PALF

Weaving frame made from wood and equipped with nails at its top and bottom is require to fabricate the woven fabric. Following the plain weave type, the kenaf yarns been arranged in the warp direction and the interwoven fabric then completed by the PALF yarns in the weft direction, as shown in figure 1. Figure 2 shows the sack needle that been used for the process and also the complete kenaf/PALF fabric.
2.3. **Composite fabrication**
Composites are fabricated via the hand lay up process using a non stick mould with measurement of 30cm x 30cm. The mould surface been cleaned before placing the woven fabric to create a smooth surface composites. The resin mixture then been poured into the mould until a desire thickness achieved. Curing process at a temperature of 25°C for 24 hours is needed before the composites been removed from the mould. Symbol representing different kenaf/PALF ratio composite are as shown in table 3.

| Kenaf/PALF ratio (%) | Symbols |
|----------------------|---------|
| 10/10                | K20     |
|                      | P20     |
| 15/15                | K30     |
|                      | P30     |
| 20/20                | K40     |
|                      | P40     |

2.4. **Testing**
In this experiment, tensile test were conducted as per ASTM D3038 standard and the size of the sample is 130 mm x 20 mm x 3.2 mm. For flexural test, the sample size is 125 mm x 13 mm x 3.2 mm and testing were done as instructed in the ASTM D790 standard. Average result from 5 samples for each test were recorded to achieve an accurate result. The morphology of fractured samples were observed using Scanning Electron Microscope (SEM).

3. **Result and Discussion**

3.1. **Tensile performance of kenaf/PALF composites at different fibre ratio**
Figure 3 shows the tensile performance result of interwoven kenaf/PALF at different fibre ratio. Regardless the fibre ratio, higher tensile strength was recorded when the load been applied along the
kenaf direction. Correct material selection for hybrid composites lead to greater performance [6]. Kenaf fibre have higher tensile strength, in comparison with the PALF and combining this two fibre in a woven fabric improved its performance and this support the finding of this study. Composite with kenaf/PALF ratio of 15/15 had the highest tensile strength compared to the 10/10 and 20/20 ratio. By the rule of mixture, higher fibres content should result in increasing tensile strength of the composite if interfacial holding is great [7]. However, when exceeding 30% fibre loading, tensile strength of composites was reduced. Similar finding was found by [8], where when the fibre content exceeding the certain volume, the strength of composite is decreased. Poor wetting due to too much fibre lead to low tensile performance of the hybrid composite.

![Figure 3. Tensile performance of kenaf/PALF composites at various fibre ratio.](image)

3.2. Flexural performance of kenaf/PALF composites at different fibre ratio
As presented in figure 4, kenaf/PALF hybrid composite with fibre ratio of 15/15 recorded the highest flexural strength compared to 10/10 and 20/20 kenaf/PALF ratio. The high bending strength of the 15/15 composite could be due to evenly distributed stress. More than one fibre in the hybrid composite create unique stress transfer mechanism that enhanced its properties. Through this unique stress transfer, final failure only happen when both fibres reach their maximum load carrying capacity [7].

Weft yarn which located at the top and bottom the warp yarn in plain weaving pattern is another factor contribute to the higher bending strength of the composite [7]. Both kenaf and PALF yarns are tightly lock due to the weaving and to break its locking system, more load is require.

![Figure 4. Flexural performance of kenaf/PALF composites at various fibre ratio.](image)
Figure 4. Flexural performance of kenaf/PALF composites at various fibre ratio.

3.3. Morphological observation of the fractures samples
SEM images of the woven composites after mechanical test are shown in figure 5. From SEM images, failure of composite usually determine by the fibre pull out, crack formation and also the gap between the fibre and the matrix [6]. The appearance of those phenomena mostly lead by the lack of resin penetration into the composite and the hydrophilic nature of natural fibre worsen the wettability between the fibre and the matrix [9].

From the SEM image in figure 5(b), fibre pull out was not observed and this proven the highest tensile strength recorded by the 15/15 sample. Fibre pull out and crack are obviously seen in the SEM image shown in figure 5(a), which support the lowest tensile strength recorded by the 10/10 samples. With intermediate tensile strength, some fibre pull out were still observed at the fracture sample of 20/20 composite, as shown in figure 5(c).

Figure 5. SEM images of kenaf/PALF hybrid composites at various fibre ratio; (a) 10/10, (b) 15/15 and (c) 20/20.

4. Conclusion
As a conclusion, it is important to note that the fibre selection play a role in determining the final performance of hybrid composites. With hybridization, fibre with lower mechanical properties still had opportunity to be explore. As in this study, kenaf fibre been really helpful in enhancing the mechanical performance of the hybrid composites and weaker PALF fibre still can have potential as reinforcement. Furthermore, greater properties achieved through weaving as both the reinforcements are tightly lock in a unique structure, making the hybrid composite possessed higher resistance towards the applied load during testing. Content of reinforcement surely had impact to the final result.
Adding the fibre amount found to increase the properties but too much fibre lead to poor wettability between the fibre and the matrix, which reduce the strength of the composites.

5. References

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