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Mechanical Properties of Hybrid Kenaf - Pineapple Leaf Fibre (PALF) Epoxy Composite For Engineering Application

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Abstract: Natural fibres nowadays have been famously investigated as alternative fibres due to the depletion of petroleum sources. There are several natural fibres such as jute, hemp, sisal, kenaf, and pineapple leaf that have been actively investigated in terms of their mechanical properties. Malaysia produces kenaf and pineapple as its main commodities. The sources of kenaf and pineapple leaf can be obtained easily. Therefore, this research is focusing on the kenaf and pineapple leaf. Previous researchers have proved that the kenaf and pineapple leaf fibres have good mechanical properties. This study aims to characterized the mechanical properties of a hybrid kenaf and pineapple leaf Fibre (PALF) epoxy composite for engineering application. Different compositions of kenaf and PALF were formulated to compare the best composition in terms of maximum stress. The tensile test was performed via the Universal Testing Machine. Hybridization of pineapple leaf fibre and kenaf fibre at a composition of 75 % pineapple leaf fibre to 25% kenaf fibre which is 87.06 MPa, shows the highest maximum stress. The result found that this composition performs better than the previous investigation of hybrid natural fibre. As a result, the findings of this study may provide a clear indication that natural fibre should be used rather than being discarded, particularly by the agricultural industry.

Keywords: Kenaf fibre, pineapple leaf fibre, hybrid, composites, tensile test

1. Introduction

Natural fibre-based composites are always applied as they have an eco-friendly nature and peculiar properties. The natural fibre has the advantage of being biodegradable and having a non-stop supply. Pineapple leaves commonly cause agricultural waste with a huge unutilised biomass. The application of hybrid pineapple leaf and kenaf fibre composite has great potential as an alternative to existing synthetic fibre composite. The problem with the currently used synthetic materials is that they are non-biodegradable, heavy and expensive. This could harm the environment because of its inability to decompose and cause pollution.

Composites have been used for many purposes in our daily lives where they enhance the material, making it lighter and more durable. The composite manufacturing method was versatile, efficient, and high-tech [1]. The four categories of fibre-reinforced composites described by their matrices are metal matrix composites (MMCs), ceramic matrix composites (CMCs), carbon/carbon composites (C/C), and polymer matrix composites (PMCs) or polymeric composites [2]. Composites are mainly used for infrastructure or transportation to ensure that they can be sustainable materials that protect the environment [3]. Fibre composites are used in construction, such as when it is added to cement to make it less

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prone to cracking [4]. Macro synthetic fibres, also known as structural synthetic fibres, have been identified as providing an alternative to steel fibres [5].

Composites are also used in modes of transportation such as rail, road, air, and maritime. Composites such as carbon fibre reinforced polymer (CFRP) are used in aircraft to boost the functionality of an aircraft, such as allowing it to be shaped into a more streamlined shape without making the material become pricier [6-7]. Composites are used in transportation to decrease the weight of the vehicle, as composite advantages are the lightweight of the material. In the automotive industry, the components inside of automobiles that consist of composites are from the exterior, interior, and under the hood area [8]. Three types of fibres can construct a composite: synthetic fibre, natural fibre, or hybrid fibre that will combine two fibre types. Natural fibre and synthetic fibre have their own classifications that have their own properties that could be used in different situations [9]. Fig. 1 shows the classification of natural fibres and synthetic fibres.

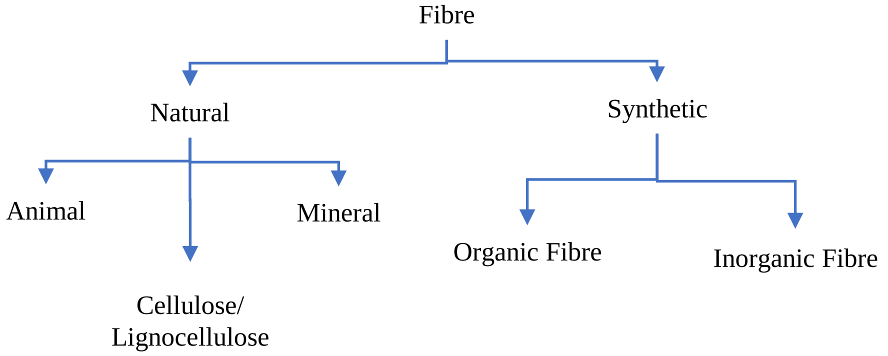

Fig.1 - The classification of natural and synthetic fibres [10].

Table 1 shows the strength limit of some natural fibres that can be employed as a composite reinforcing agent from the previous study. This natural fibre has been studied and has been hybridized together to study the tensile strength of the fibre when it was mixed together. Natural fibres have low water resistance, durability, and fiber/matrix interfacial bonding, which reduces the final composite properties and limits their use in industry [11–15].

Table 1 - The analysis on natural fibre characteristic. [11-15]

Properties	Density (g/cm^3)	Tensile strength (MPa)	Young's Modulus (GPa)	Elongation at break (%)
Jute	1.3 – 1.46	393 – 800	10 – 30	1.16 – 1.8
Flax	0.6 – 1.5	345 – 2000	12 – 80	1.2 – 3.2
Pineapple	0.8 – 1.6	400 – 627	1.44	14.5
Bamboo	1.25	140 – 230	11 – 17	–
Sisal	1.33 – 1.5	400 – 700	9.0 – 38.0	2.0 – 14
Coir	1.2	175 – 220	4 – 6	15 – 30
Kenaf	1.5	930	53	1.6
Ramie	1.5	220 – 938	44 – 128	2.5 – 3.8

Previous studies on natural fibre hybridization have mostly focused on mechanical properties such as tensile, flexural, and impact strength, as well as physical properties employing tensile and flexural testing. Some studies, such as the hybrid of jute and ramie fibres [16] and the hybrid of banana, jute, and sisal fibre [17], focus on the mechanical properties of the hybrid. Table 2 is a summary of the data analysis from a number of previous studies on this type of hybridization, as well as the test data from these studies, such as the highest stress force.

Table 2 - Data on previous studies that been conducted

Best material	Maximum tensile data	Maximum flexural data	Maximum compression data	Impact data
Jute – Ramie [16]	44.72 MPa	82.27 MPa	23.13 MPa	-
Sisal – Jute [17]	Approx. 34 MPa	Approx. 46 MPa	-	-
Kenaf – Banana [18]	72.35 MPa	129.74 MPa	-	15.9 kJ/m^2
Coil – Oil Palm EFB [19]	30.8 MPa	53 MPa	-	29.2 J/m
Jute – Flax [20]	36.38 MPa	112.25 MPa	-	38.78 kJ/m^2

Kenaf and pineapple are among the main commodities in Malaysia. Pineapple leaves become waste in the majority of the pineapple area. Therefore, the combination of kenaf and Pineapple leaf Fibre (PALF) was selected in this study due to the abundance criteria, especially in Malaysia. The goal of the study is to find out how the composition of a hybrid kenaf and PALF epoxy composite affects its mechanical properties for use in engineering.

2. Methods

In this research, the experiment starts with the preparation of the materials, which were kenaf weave and pineapple leaf weave. The epoxy type EpoxAmite 100 was used to make the composite kenaf, which was then aligned in a unidirectional direction and carefully divided into rectangular formed shapes ($127\,mm \times 12.7\,mm \times 3\,mm$). The specimens is then tested using a universal testing machine (UTM) to determine the force required to break the specimen. Fig. 2 shows the flow of sample fabrication.

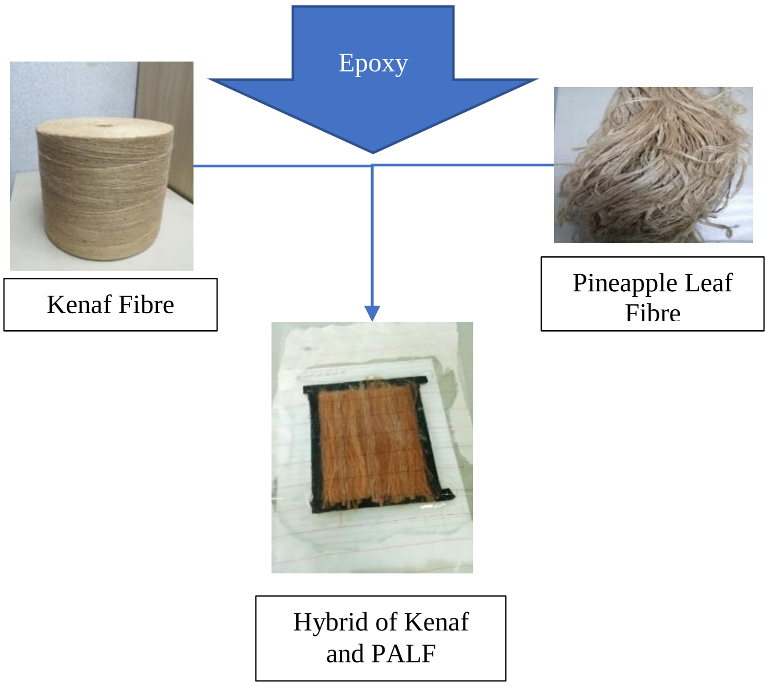

Fig. 2 - Sample Preparation visualization

a. Specimen Fabrication

The sample was fabricated with the dimensions of 150 mm x 120 mm x 3 mm before it was fitted into a specimen sized according to the ASTM D3039 standard, which has a height of 127 mm, a width of 12.7 mm, and a thickness of 3 mm. Fig. 3 shows the visualization of the sample size during fabrication and composition of the kenaf and PALF.

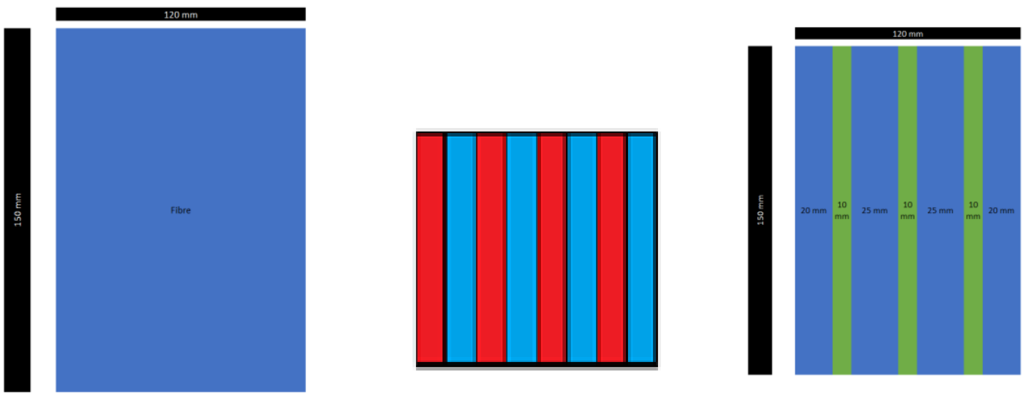

Fig. 3 - (a) configuration for 100 : 0 (b) configuration for 50 : 50 (c) configuration for 25 : 75

b. Procedure

The samples were labelled to avoid mistakes when making the test because all samples have a similar appearance. Fig. 4 shows the compiled sample before the test and during the test. The samples were tested on the Universal Testing Machine as shown in Fig. 5. Five of the refined results from each type were taken to be tested on the Universal Testing Machine for their mechanical behavior. The tensile results were taken to be observed and analysed.

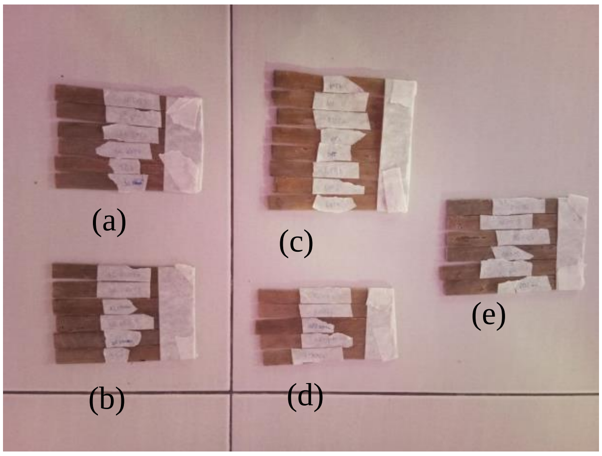

Fig. 4 - The type of specimen, (a) The 25 pineapple leaf fibre to 75 kenaf fibre percentage; (b) The 75 pineapple leaf fibre to 25 kenaf fibre percentage; (c) The 100 pineapple leaf fibre to 0 kenaf fibre percentage; (d) The 0 pineapple leaf fibre to 100 kenaf fibre percentage; (e) The 50 pineapple leaf fibre to 50 kenaf fibre percentage

Fig. 5 - Sample on Universal Testing Machine

3. Result and Discussion

The data for maximum stress and force for each composition is presented in Fig. 6 and Fig. 7. The Young's modulus or modulus of elasticity of each sample can be obtained from the slop of each stress-strain graph line. The PALF graph line present shows a slow break rather than the other composition of the fibre. In all of the other graphs, the slope of the graph line shows a sudden drop, proving it does not undergo the necking phase. This situation shows that the PALF shows high ductility as compared to kenaf fibre and is supported by previous findings such as Pratik M. Waghmare, et. al [18] and Rizal, M.Z.A. et. al [21]. The combination of 75% PALF and 25% kenaf also presents a good ductility characteristic. Because of its ductility, this result suggests that the PALF can be used in a variety of engineering applications. The ductility characteristic can avoid sudden failure due to any external forces exerted on the structure.

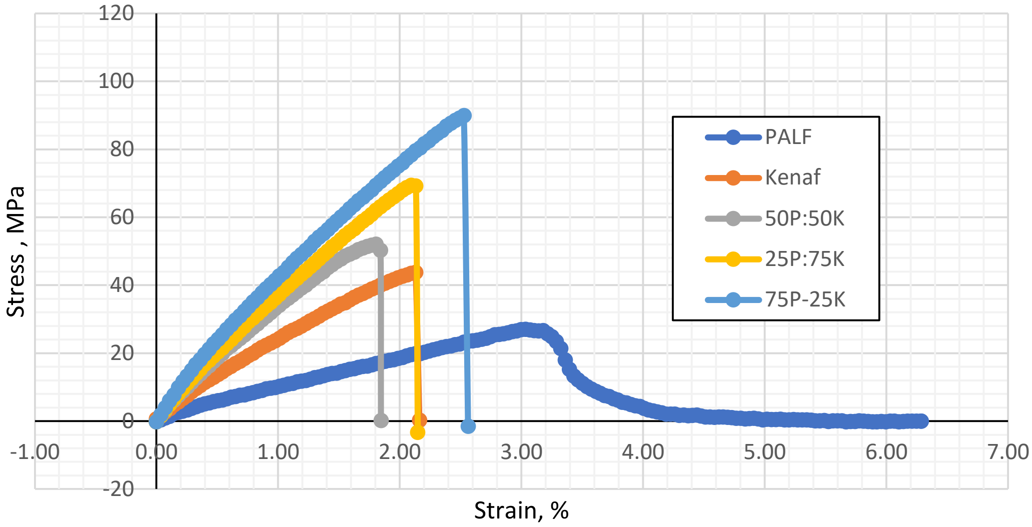

Fig. 6 - Stress – Strain Comparison between each sample

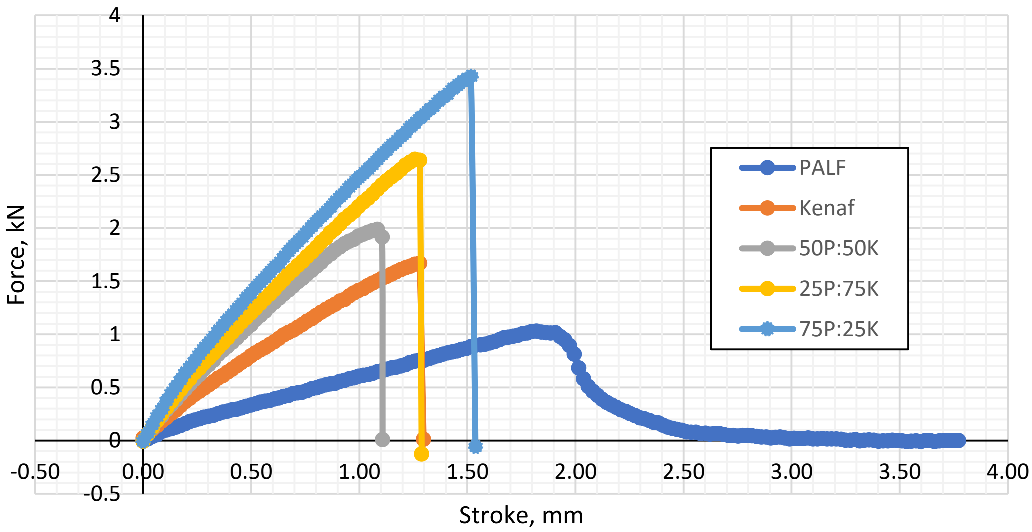

Fig. 7 - Maximum force for each sample

Table 3 shows the average result for each test conducted. Based on the experiment, 75:25 Fraction Percentage of PALF to Kenaf Fiber can withstand the most force to break the sample, which is 3.32 kN at the most stress, which is 87.06 MPa.From the data obtained. The PALF is the most flexible because it can stretch almost 5 mm without breaking.

Table 3 - Average data for all configuration

Name	Unit	Characteristic value				
		PALF	Kenaf	50P:50K	25P:75K	75P:25K
Young's modulus	MPa	7.97	88.48	27.11	32.76	35.46
Maximum Force-TD1	kN	0.92	1.62	2.00	2.65	3.32
Maximum Stroke point -TD2	mm	1.77	1.22	1.14	1.26	1.42
Maximum point-Stress	MPa	24.05	42.55	52.41	69.43	87.06
Maximum point-Strain	%	2.95	2.03	1.90	2.09	2.37
Breaking point-TD1	kN	0.11	0.01	-0.01	-0.13	0.13
Breaking point-TD2	mm	4.43	1.24	1.17	1.29	1.44
Breaking point-Stress	MPa	2.78	0.24	-0.34	-3.32	3.45
Breaking point-Strain	%	7.38	2.06	1.95	2.15	2.40

The result of the test has shown that the experiment has given a good result as it has a little improvement in the maximum stress. The comparison of the data is listed in Table 4.

Table 4 - The maximum forces achieved for 75: 25 Fraction Percentage of Pineapple leaf Fibre to Kenaf fibre sample

Material	Maximum Stress , MPa
PALF	24.05 MPa
Kenaf	42.55 MPa
50 PALF : 50 Kenaf	52.41 MPa
25 PALF : 75 Kenaf	69.43 MPa
75 PALF : 25 Kenaf	87.06 MPa
Jute – Ramie [16]	44.72 MPa
Sisal – Jute [17]	Approximately 34 MPa
Kenaf – Banana [18]	72.35 MPa
Coil – Oil Palm EFB [19]	30.8 MPa
Jute – Flax [20]	36.38 MPa

4. Conclusion and Recommendation

The result of the investigation shows that the balanced composition does not make the material tougher. The result obtained showed that a 75:25 fraction percentage of PALF to kenaf fibre has a higher elastic modulus and force required to break the specimen than the 25:75 fraction percentage of PALF to kenaf fibre. Even though when 100:0 Fraction Percentage of PALF to kenaf fibre is used, it has the lowest force required to break the specimen, replacing 25% of the PALF makes the sample more elastic and tougher than the other material.

A few recommendations can be proposed to the next researchers to improve this research's outcomes. The first recommendation is to conduct a more detailed composition analysis of the researched fibres. The research can also be improved by creating a composite on which more tests can be conducted to analyse the fibres' properties. The consideration to the material breaking during mounting at the Universal Testing Machine should be considered highly as this is the failure that should be prevented.

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