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Mechanical Properties of Hybrid Pineapple Leaf and Kenaf Fibers Composite

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Abstract

The use of natural fibers such as pineapple leaf (PALF) and kenaf fibers in composite materials has gained attention due to their potential to provide improved mechanical properties over traditional materials. Furthermore, there is significant opportunity for this idea to be employed in high-value sectors like building, aircraft, and automobiles. Therefore, the study aims to investigate the mechanical properties of hybrid kenaf fibers and PALF composite material for aircraft applications. The hybrid composite ratio between kenaf fiber and PALF varies into three different ratios. The kenaf fiber:PALF ratio is 60:40, 40:60, and 50:50, respectively. The samples were fabricated via a hand-layup process. Tensile and flexural testing were conducted to analyze the mechanical properties of the hybrid composite. The Scanning Electron Microscope (SEM) was employed to investigate the structure morphology. The tensile testing shows that the 40:60 ratio composite has the highest maximum stress (69.14 MPa). Besides that, the 60:40 ratio composite has the maximum flexural strength (129.35 MPa). The SEM investigation reveals that the failure occurs due to matrix deformation, fiber breaking, and fiber pullout. The results show that the hybrid composite has good performance as compared to the existing material in aviation, such as for food trays, inner walls, and low-critical composite parts. Hence, it has a big potential for further enhancement with regards to weight reduction, increasing fuel efficiency, and lowering carbon emissions in the aviation sector.

1. Introduction

Composite materials are widely used in all types of applications, varying from simple household products to complex engineering structures [1–5]. Properly designed composite material can achieve a wide range of high-performance properties [5]. It is important to analyze the mechanical properties of any composite material before designing products and using it in any application [6–8]. Composite materials are widely used in both civil and military aircraft [2, 9]. Composites made of natural fibers are the subject of much research because of their special qualities and environmental friendliness [10]. The benefits of natural fibers are their simple handling, biodegradability, and availability. Even though natural fibers have excellent mechanical properties, they vary depending on the plant source, species, geography, and so on [10, 11]. Several natural fiber composites have been investigated, such as olive tree leaves (OTL) [12], date fiber [13–16], kenaf [16, 17], pineapple leaf fiber [11, 17, 18], napier grass [19, 20], flax [21–23], etc. Thus, it is important to evaluate the engineering properties of the natural fiber composite materials used in the aircraft.

There is research on the potential of date fiber for structure enhancement [16, 24]. The weight ratio of the reinforcement and matrix in the fabrication of Date Palm Fiber (DPF)/Kenaf Fiber (KF)/epoxy hybrid composites is specified at a ratio of 50% fiber and 50% resin. The dissolved polyacrylonitrile fiber DPF and kenaf fiber KF among the reinforcements ranged from 30 to 70% [16]. Table 1 lists three fiber ratios for composites. DPF and KF are steeped in distilled water with 6% NaOH concentration for six hours during the production procedure. After that, the fibers were utterly cleaned under running water, the pH was balanced, and they were dried in an oven for 48 hours. Natural fibers are moistened to a level of 6-8% and ground to a thickness of 0.5 to 1 mm (measured by a digital moisture meter). The results show that KF improved the mechanical and thermal properties of DPF. Due to the enhanced matrix/fiber bonding, the hybrid fibers in epoxy composites successfully increased the flexural strength and dynamic mechanical properties.

Table 1 *Formulation of composites [19]*

Hybrid composites	Date palm fiber (DPF) (wt. % of fiber)	Kenaf fiber (KF) (wt. %of fiber)	Epoxy resin (wt.% of composite)
3DPF7K	30	70	50
1DPF1K	50	50	50
7DPF3K	70	30	50

One example of natural fiber research on aircraft pertains to aircraft tray tables. These tables are used to serve food and drinks during flights, and they also provide passengers with a place to work or eat during the flight. The tray table is usually made from lightweight aluminum or plastic, making it easy to fold and store. The use of hybrid pineapple leaf and kenaf fibers in composite materials has the potential to impact the mechanical properties of aircraft tray tables [25,26]. These natural fibers have high tensile and flexural strengths, making them suitable for structural applications. These fibers can reinforce the tray table, thereby increasing its strength and stiffness [26]. It will not only improve the durability of the tray table but also reduce the weight of the aircraft, resulting in fuel savings and a reduction in carbon emissions. In addition to their structural benefits, combining hybrid pineapple leaves and kenaf fibers in composite materials can also have environmental benefits. These fibers are renewable and sustainable resources, making them a more environmentally friendly alternative to traditional synthetic fibers. This can lessen the overall environmental impact of aircraft tray tables and contribute to a more sustainable aviation industry.

In general, this study aims to explore a new and innovative solution for improving the mechanical properties of aircraft tray tables. The use of hybrid pineapple leaf and kenaf fibers in composite materials has the potential to not only improve the durability of the tray table but also reduce the weight of the aircraft, resulting in fuel savings and a reduction in carbon emissions. Additionally, the use of natural fibers in composite materials can also have environmental benefits by reducing the overall environmental impact of the aviation industry. Therefore, the objective of this research is to study the effect of hybrid pineapple leaf (PALF) and kenaf fiber content on mechanical properties (tensile and flexural properties) of composites as well as investigate the microstructure morphology of hybrid PALF and kenaf fiber composites.

2. Methodology

The use of pineapple leaf fiber and kenaf fiber is chosen due to their potential as sustainable and environmentally friendly materials. The three different ratios of 60:40, 40:60, and 50:50 are selected to study the effect of varying fiber content on mechanical properties.

A mold cavity of dimensions 200 x 25 x 3.5 mm is used for stacking to form composite laminates. The composite industry commonly uses a 1:9 ratio to mix the fibers with epoxy. The mixture is then cured for 24 hours to cure the epoxy and bonding of the fibers properly. The hand lay-up process is then used to lay the fibers on the flat glass surface.

The mechanical properties of the composite tray table are evaluated utilizing a universal testing machine. The conducted tests include tensile tests to determine tensile strength and modulus of elasticity, as well as flexural tests to evaluate flexural strength and modulus of elasticity. The microstructure of the composite material was studied using a scanning electron microscope (SEM) for analyzing the distribution and orientation of fibers within the matrix.

3. Results and discussion

Fig. 1 and Table 2 show mechanical testing results at different kenaf/PALF ratios. The stiffness of a material is represented by Young's modulus, also referred to as the modulus of elasticity, which is determined as the slope of the stress-strain curve. The results show that the 50:50 kenaf:PALF ratio presents the highest Young's modulus values (2.32 GPa) as compared to 40:60 and 60:40, which are 1.99 GPa and 1.61 GPa, respectively. On the other hand, the 40:60 kenaf:PALF ratio shows the highest maximum stress, which is 69.14 MPa. The composite with a 60:40 ratio of kenaf to PALF had an average maximum stress of 57.71 MPa. The composite with a 50:50 ratio of kenaf to PALF had an average maximum stress of 61.70 MPa. The Young's modulus values vary at the different ratios of kenaf to pineapple fibers. Based on previous research, the results of this study indicate that the percentage of PALF to kenaf fiber significantly influences the mechanical properties of the composite materials. It is observed that PALF exhibited higher ductility compared to kenaf fiber.

Table 2 *Average data for all configuration for tensile testing*

Ratio of Kenaf Fiber:PALF	Average max stress(MPa)	Young's modulus(GPa)
60:40	57.71	1.61
50:50	61.70	2.32
40:60	69.14	1.99

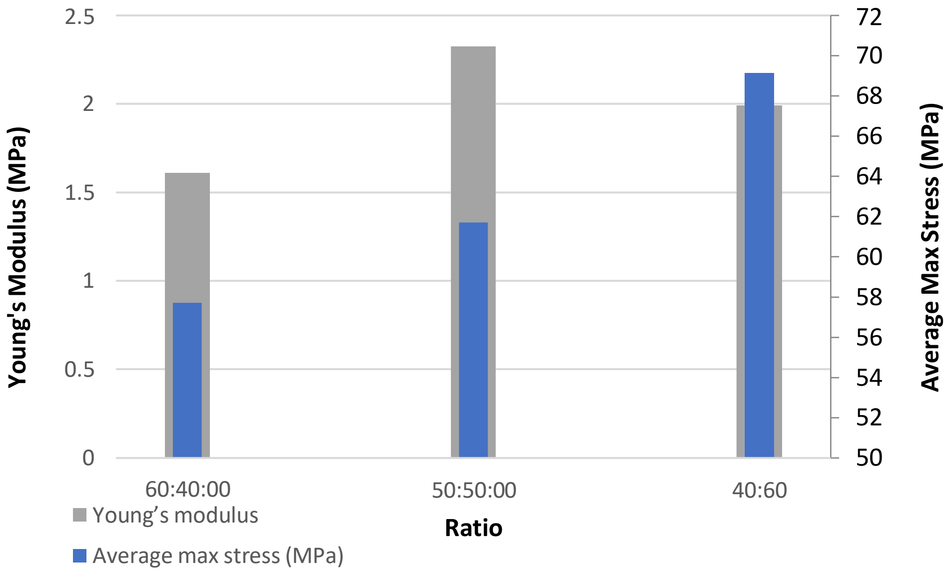

Fig. 1 *Average data for all configuration for tensile testing*

Table 3 demonstrates the correlation between average maximum flexural strength and average flexural modulus and the ratio of kenaf fiber to PALF. When the ratio of the two fibers fluctuates, it is possible to identify clear trends in the behavior of these features through data analysis. The ratio of 60:40 results in the highest average maximum flexural strength, 129.35 GPa, demonstrating that a higher percentage of kenaf fiber contributes to increased strength. The 40:60 ratio yields the lowest average maximum flexural strength, 99.25 GPa, suggesting that a higher PALF percentage leads to weaker materials. Figure 3 reveals that combining PALF and kenaf fiber in a 50:50 ratio can increase the average flexural modulus to a maximum value of 177 MPa. This indicates that an equal combination of the two fibers yields the highest average flexural modulus. The average flexural modulus specifically reaches its lowest value of 52.6 MPa at the 40:60 ratio.

Comparing these findings with the previous findings, some similarities and differences have been observed. It discusses various hybrid composites involving different fiber combinations and fabrication techniques. Researchers studied PALF/OTL/epoxy matrix hybrid composites and found that reducing the fiber loading of PALF reduced the flexural properties [12]. This aligns with the graph's observation that a higher proportion of pineapple fiber leads to weaker materials.

Table 3 *Average data for all configuration for flexural testing*

Ratio of Kenaf Fiber:PALF	Average Max Flexural Strength (MPa)	Average Flexural Modulus (MPa)
60:40	129.35	59.8
50:50	115.79	177
40:60	99.25	52.6

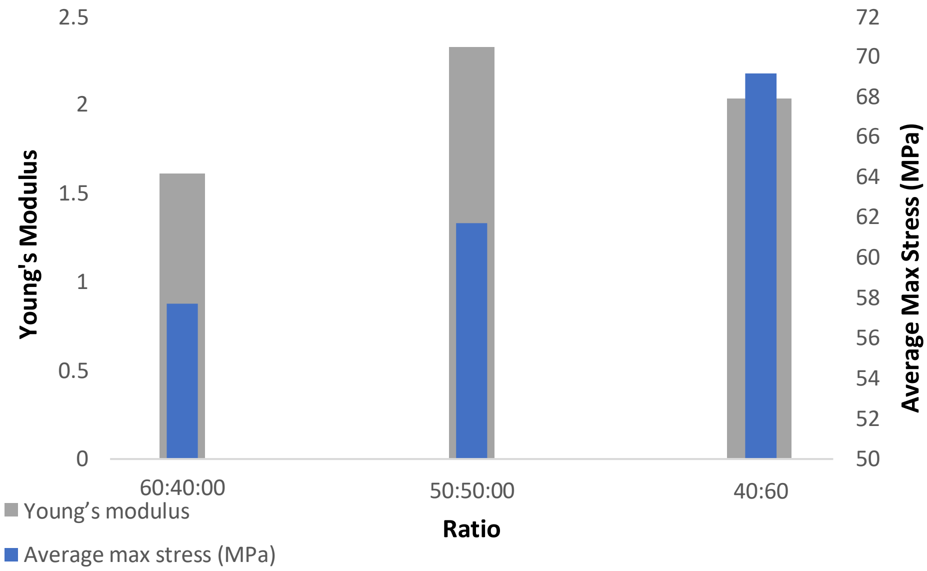

Fig. 2 *Average data for all configuration for flexural testing*

Fig. 4 shows morphology characterization of flexural testing for 40:60, 50:50, and 60:40 ratios of Kenaf/PALF ratios. Referring to Fig. 4(a), during fracture or flexural testing, certain fibers may partially or totally peel away from the epoxy matrix. A protruding fiber end on the composite surface is a sign of this phenomenon. Referring to Figure 4(b), it shows a fiber breakage, which means in rare instances, stress concentration areas or insufficient epoxy bonding might cause the fibers to break. It is possible to discern broken fiber fragments on the composite surface. Fig. 4(c) illustrates the formation of matrix deformation. The epoxy matrix may experience matrix deformation, particularly in regions with high stress levels. Surface abnormalities, such as small bulges or depressions, may be the result of this.

Fig. 5 shows morphology characterization of tensile testing for 40:60, 50:50, and 60:40 of Kenaf and PALF ratios. Fig. 5(a) reveals that air bubbles contribute to the tensile failure of the composite material. Due to the stress concentrator function of these air bubbles, there are more localized stress concentrations and less overall strength, as shown in Fig. 5(b). The lack of suitable degassing during the fabrication process or the insufficient impregnation of the fibers with the epoxy resin may have contributed to the air bubbles, as shown in Figure 5(c).

Overall, this study shows how important it is to get the resin to penetrate properly, bond the fibers to the matrix well, and choose the right fiber ratio in order to improve the mechanical properties of kenaf/PALF hybrid composites. The morphology characterization using SEM images provides valuable insights into the failure mechanisms and structural features that contribute to the mechanical performance of these composites.

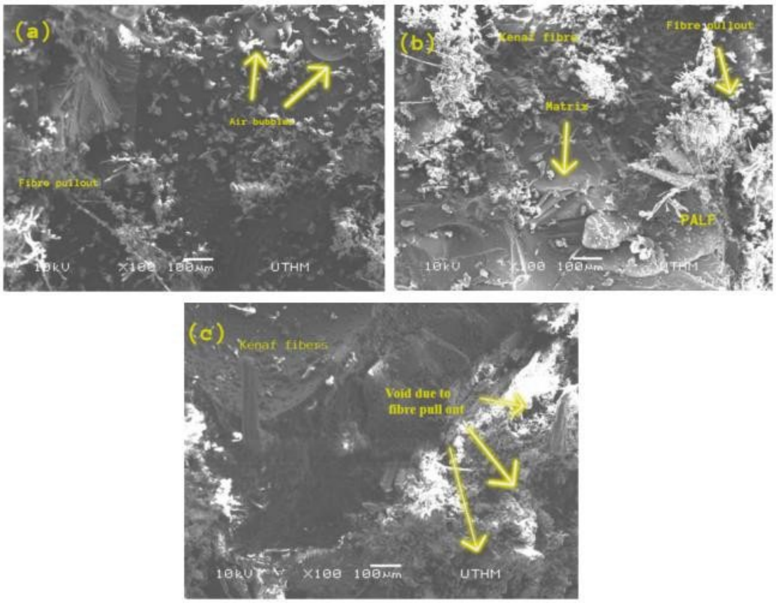

Fig. 4 *Morphology characterization of flexural testing for (a) (40 : 60) ratio (Kenaf : PALF), (b) (50 : 50) ratio (Kenaf : PALF), (c) (60 : 40) ratio (Kenaf : PALF)*

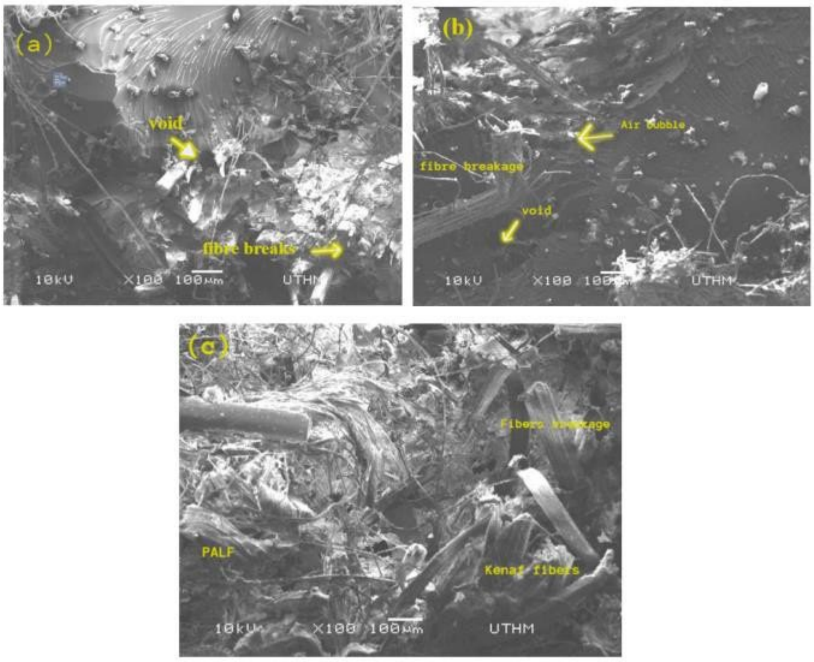

Fig. 5 *Morphology characterization of tensile testing for (a) (40 : 60) ratio (Kenaf : PALF), (b) (50 : 50) ratio (Kenaf : PALF), (c) (60 : 40) ratio (Kenaf : PALF)*

4. Conclusions

This study aims to investigate the effect of PALF/kenaf fiber ratio on the mechanical properties (specifically tensile and flexural properties) and microstructure morphology of hybrid composites. In conclusion, the ratio has a major impact on the mechanical properties of kenaf/PALF composites. A 50:50 ratio yields the greatest Young's modulus (2.32 GPa) and flexural modulus (177 MPa), indicating ideal stiffness and flexibility. On the other hand, a 40:60 ratio indicates greater strength but decreased flexibility since it yields the highest maximum stress (69.14 MPa) but the lowest flexural modulus (52.6 MPa). The 60:40 ratio achieves the highest flexural strength (129.35 GPa), highlighting the impact of increased kenaf content on strength. Overall, the study demonstrates that adjusting the kenaf/PALF ratio can customize the mechanical properties of the composite for specific purposes. Raw materials manufactured from kenaf fiber and PALF are extremely versatile. However, the processing performed is a conventional method. To further improve the performance of the composition, some suggestions are made for future research to improve the outcomes of the research. Future research should investigate alternate processing approaches and cutting-edge manufacturing techniques to optimize the fabrication process. Examining fiber treatments and surface alterations could potentially enhance the performance of the composites.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Wan Amin Khalili Wan Hashim, Ahmad Hamdan Ariffin;* ***data collection:*** *Wan Amin Khalili Wan Hashim;* ***analysis and interpretation of results:*** *Wan Amin Khalili Wan Hashim;* ***draft manuscript preparation:*** *Wan Amin Khalili Wan Hashim, Ahmad Hamdan Ariffin, Mohd Fadhli Zulkafli. All authors reviewed the results and approved the final version of the manuscript.*

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