UNIVERSITI PUTRA MALAYSIA

LOW VELOCITY IMPACT ANALYSIS OF PINEAPPLE LEAF/KENAF FIBRE-REINFORCED VINYL ESTER HYBRID COMPOSITES FOR STRUCTURAL APPLICATIONS

ALI AHMAD BIN MAZLAN

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By

ALI AHMAD BIN MAZLAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Master of Science

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February 2021

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Recently, all the government legislation as well as environmental consciousness has enforced the industrial and academic researchers to produce eco-friendly, lightweight and renewable composite materials. The study of natural plant fibres (pineapple, kenaf etc.) as reinforcement in polymer matrix has rose rapidly due to their unique properties such as low in cost, biodegradable and renewable. Pineapple leaf fibre (PALF) and kenaf fibres (KF) are one of the natural fibres that being widely used as a reinforcement in the polymer matrix composites. Vinyl ester (VE) resin was used as a matrix in this research work. The present research works investigated the effect of fibre length of PALF (short, mixed and long), the effect of fibre orientation angle of woven KF on the tensile and flexural properties of PALF/VE composites. This research work also investigated the low velocity impact (LVI) and compression after impact (CAI) properties. Besides mechanical testing, thermal testing such as thermogravimetric analysis (TGA) and dynamic mechanical analysis (DMA) were also conducted. The composites with long (30 mm) fibres were chosen to be hybridized with woven KF (PALF/KF/VE hybrid composites) for further investigation which varying the fibre orientation angle of KF (0°/90°, 30°, 45° and 60°). The hybrid composites were fabricated with five layers (2KF/PALF/2KF) by using the hand lay-up technique. As a result, the hybrid composites with 0°/90° orientation showed the optimum mechanical properties and was chosen to be tested further with the LVI with different level of energy (5 J, 10 J and 15 J) and CAI testing. From the LVI testing, the hybrid composites can hold up to 15 J of impact energy. CAI results showed that the hybrid composites impacted with 5 J gave the optimum value of compressive strength than 10 J and 15 J. TGA and DMA testing showed that the incorporation of fibres in the matrix enhance the thermal stability of the composites.

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ANALISIS IMPAK KELAJUAN RENDAH TERHADAP DAUN NENAS/KENAF KOMPOSIT KACUK ESTER VINIL BERTETULANG UNTUK APLIKASI STRUKTUR

Oleh

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Terbaru, Semua perundangan kerajaan serta kesedaran alam sekitar telah membuatkan para penyelidik industri dan akademik untuk menghasilkan bahan komposit yang mesra alam, ringan dan boleh diperbaharui. Kajian gentian tumbuhan semula jadi (nenas, kenaf, dan lain-lain) sebagai tetulang dalam matriks telah meningkat dengan cepat kerana sifat unik mereka seperti rendah kos, biodegradasi dan boleh diperbaharui. Gentian daun Nenas (PALF) dan gentian kenaf (KF) adalah salah satu gentian semulajadi yang digunakan secara meluas sebagai tetulang dalam komposit matriks. Kerja penyelidikan yang dilakukan sekarang ialah berkaitan dengan kesan panjang PALF (pendek, campuran dan panjang) pada sifat tegangan dan lenturan daripada komposit PALF/VE. Komposit dengan gentian panjang (30 mm) telah dipilih untuk menjadi kacukan dengan gentian kenaf tenunan KF untuk siasatan lanjut. Kesan orientasi gentian (0°/90°, 30°, 45° dan 60°) gentian kenaf tenunan pada komposit hibrid telah diperiksa secara mekanikal (tegangan dan lenturan) dan termal (TGA dan DMA). Keputusan menunjukkan komposit hibrid dengan orientasi 0°/90° dipilih untuk diuji lebih lanjut dengan kesan halaju rendah (LVI) dengan tahap tenaga yang berbeza (5 J, 10 J dan 15 J) dan ujian mampatan selepas kesan halaju (CAI). Dari ujian LVI, komposit hibrid boleh menanggung sehingga 15 J. Keputusan CAI menunjukkan bahawa komposit hibrid yang dikenakan dengan 5 J memberikan bacaan optimum kekuatan mampatan berbanding 10 J dan 15 J.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the Master of Science. The members of the Supervisory Committee were as follows:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

UPM	Universiti Putra Malaysia
MPIB	Malaysian Pineapple Industry Board
PALF	Pineapple Leaf Fibre
KF	Kenaf Fibre
LVI	Low Velocity Impact
CAI	Compression After Impact
TGA	Thermogravimetric Analysis
DMA	Dynamic Mechanical Analysis
DAP	Diammonium Phosphate
TPU	Thermoplastic Polyurethane
VE	Vinyl Ester

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LIST OF SYMBOLS

cm	Centimeter
°	Degree
°C	Degree celsius
GPa	Giga pascal
mg	Milligram
g/cm3	Gram per cubic centimeter
g/m2	Gram per cubic meter
g/ml	Gram per mililiter
MPa	Mega pascal
µm	Micrometer
mm	Millimeter
mm/min	Millimeter per minute
%	Percentage
wt%	Weight percentage

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Pineapple, ananas comosus is a perennial plant that has a height and width of 1.0-2.0 meters. It belongs to the family of Bromeliaceae (Wijeratnam, 2015). On the margin of pineapple, the green leaves may stripe with red and yellow colour. The leaves can extend about 50 to 180 cm length (Sibaly & Jeetah, 2017). As it started to bloom, the red or purple colour flowers will be elongate. To bear some fruit, the plant need about 200 days after blooming of flowers (Leão et al., 2015). It is suitable to be planted at well drained organic sandy loam with the temperature range from 28 °C to 35 °C. Usually, it can stay alive for about 4 years. Figure 1.1 shows the pineapple leaves and its fruit (Asim et al., 2015).

Figure 1.1: Pineapple leaves and its fruits (Asim et al., 2015)

Malaysia is one of the large pineapple fruits producers in Asia as much as Hawaii. Abundant pineapple plants that being planted in Malaysia such as Moris, Josapine, Yankee and others. The Malaysian Pineapple Industry Board (MPIB) expected in 2020, the production of pineapple will increase from 335,000 metric tons up to 700,000 metric tons. Thus, the number of pineapple wastes such as their leaves will be increased too. As the number of pineapple leaves increased, there will be high supply of pineapple leaves which can be produced into fibres.

The production of pineapple leaf fibre (PALF) is abundant for industrial purpose. The PALF has been extensively used in the production of textile fabric

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such as embroidered handkerchief, shirt, and footwear. Figure 1.2 and Figure 1.3 show the PALF after being extracted (Asim et al., 2015). PALF was white in colour, glossy and smooth as silk. Compared to other natural fibres, PALF has softer surface, and it maintains its colour.

Figure 1.2: Extraction of pineapple leaves (Asim et al., 2015)

Figure 1.3: Pineapple leaf fibre (PALF) (Asim et al., 2015)

In term of the strength and performance of natural fibres, PALF was one of the natural fibres that provide good performance compared to other natural fibres such as banana, hemp, jute, sisal and flax fibres (Shiju et al., 2015). For example, PALF has better mechanical strength compared to jute fibres in the making of fine yarn (Asim et al., 2015). Another example mentioned that PALF has high cellulose content that resulted in high tensile and flexural properties compared to flax, sisal, cotton and jute fibres (Mittal & Chaudhary, 2018). The usage of PALF in the real structural application is still new and no previous research that really work on the PALF in the real application. This matter has driven the interest of many researchers to prove the high strength of PALF scientifically, thus enabling its application in the real and wider fields. Another natural fibre that has good mechanical properties is kenaf fibre.

Kenaf plant, Hibiscus Cannabinus belongs to the Malvaceae family. Kenaf is a wild dicotyledons plant of subtropical and tropical parts of Africa and Asia. Kenaf is a hard, solid and intense plant with a stringy stalk, bug-harm resistant and contain a little amount of or no pesticide (Elsaid et al., 2011).

Figure 1.4 and Figure 1.5 show the kenaf plantation and fibre (Ramesh, 2016). There were three types of kenaf fibre (KF); bast, core, and pith (Karimi et al., 2014). However, most of the research works that have been conducted used bast and core (Abdul Khalil et al., 2010).

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Figure 1.4: Kenaf leaves (Ramesh, 2016)

Figure 1.5: Kenaf fibre (KF) (Ramesh, 2016)

Kenaf has high content of cellulose beside having a fibrous stalk that make the kenaf as hardy plant. It has high resistance towards the insect and able to grow under the wide range of climatic condition. The ability to adapt with various soil enable the kenaf plant to grow effectively.

The researchers have high interest in the kenaf as it can accumulates the carbon dioxide at high rate and absorb the nitrogen and phosphorus in the soil. Different location of fibres on the kenaf plant led to different physical and properties of the kenaf.

1.2 Problem Statement

Nowadays, many researchers and scientists are working on the usage of natural fibres in real life application instead of petroleum-based fibres (Ismail et al., 2019; Mazlan et al., 2020; Namvar et al., 2014). However, a lot of research work must be conducted as the properties of natural fibres are inconsistent. The mechanical properties of natural fibres have bigger inconsistencies in the previous literature, and it affect their respected composites which make their mechanical properties varied (Mathur, 2021). It was concluded that for the same polymer matrix, different fibre loading and types, even for fibres treatment, can lead to different composite properties. As a newly materials that wanted to be implemented in the real-life application, the information regarding on the mechanical properties of the natural fibres must be deeply investigated.

In Malaysia, most of the pineapples planted were in Selangor, Kelantan, Pulau Pinang and Johor. There is about 15,649 hectares of pineapple being planted that produced about 335,000 metric tons wastes. If it is being fully utilized, the economy of the country can be enhanced. The pineapple only takes one to two years to grow, making it one of fast-grow plants in Malaysia. Thus, the

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abundance amount of pineapple wastes will provide a good supply for various application. However, limited information due to the few research and developments activities on the Malaysian pineapple affect the process of pineapple commercialization.

The potential of hybridization with other natural fibres to enhance the mechanical properties of hybrid composites is investigated in this work. It is important to have various parameters to maximize the performance of hybrid composite. The variation of fibres length and fibred orientation should be identified in fabricating the new materials.

Therefore, in determining the mechanical properties of natural fibre reinforced composite, low velocity impact is one of the mechanical testings to determine the ability of the composite. For instance, during flying the airplane, the possibility to face the air turbulence is always high and unpredictable. Jostling of luggage on the aircraft floor, seats, food tray table or cabin showed that the importance of impact properties of materials of aircraft parts is essential. Thus, the ability of natural fibre composites that can withstand load and force can be obtained by doing impact testing.

1.3 Research Objective

The present research work aims to investigate the effect of fibres length of PALF and fibre orientation angle of woven KF on PALF/KF/VE hybrid composites by using tensile, flexural, low velocity impact and compression after impact testing.

The research work is divided into four different objectives. The objectives in this work are:

i. To determine the effect of fibre length of PALF on the mechanical properties of PALF/VE composites in static (tensile and flexural) and dynamic testing (dynamic mechanical testing).
ii. To investigate the effect of fibre orientation angle of woven kenaf fibres on the mechanical properties of PALF/KF/VE hybrid composites in static and dynamic testing.
iii. To analyse the thermal properties of PALF, KF and its composites.
iv. To investigate the low velocity impact (LVI) and compression after impact (CAI) properties of PALF/KF/VE hybrid composites.

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1.4 Scope of study

i. The PALF used in this research work was in yarn form.
ii. There is no further surface modification on the yarn PALF and woven KF.
iii. The research work has been limited to experimental evaluation of mechanical and thermal properties of PALF and its composites for structural application.
iv. The composites were fabricated through hand lay-up method.
v. The mechanical (tensile, flexural, LVI and CAI) and thermal (TGA and DMA) properties were evaluated.
vi. The LVI testing was not performed until full penetration to obtain the maximum impact that the hybrid composites can withstand as well as to continue with CAI testing.

1.5 Layout of Thesis

This thesis consists of five chapters. The layouts of the thesis are as follows:

i. Chapter 1, Introduction: This chapter provides an overview about pineapple and its fibres, PALF as well as the kenaf and its fibre, KF. The problem statement, research objectives and scope of study are also included in this chapter.
ii. Chapter 2, Literature Review: This chapter reviews the previous research studies on composites related to the research work conducted.
iii. Chapter 3, Materials and Methodology: This chapter provides a detailed description on the material used and fabrication of composites.
iv. Chapter 4, Result and Discussion: This chapter provides the discussion of the TGA. DMA, tensile, flexural, LVI and CAI result for PALF, KF and its hybrid composites. Critical and damage analysis of impacted specimen also being presented in this chapter.
v. Chapter 5, Conclusion and Recommendation: This chapter concludes the research work based on the objectives of the research work. Finally, the suggestions for future research work also being included in this chapters.

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