INVESTIGATION OF FATIGUE BEHAVIOUR OF PINEAPPLE LEAF FIBER REINFORCED POLYLACTIC ACID COMPOSITE

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree Of Manufacturing Engineering (Hons.)

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DECLARATION

I hereby, declared this report entitled "Investigation of Fatigue Behaviour of Pineapple Leaf Fibre Reinforced Polylactic Acid Composited" is the result of my own research except as cited in references.

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Date 3 / 6 / 2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for degree of Bachelor of Manufacturing Engineering (Hons.).
The member of the supervisory committee is as follow:

....

(DR . ZALEHA BINTI MUSTAFA)

ABSTRAK

Bahan gentian polimer bertetulang gentian semulajadi merupakan bidang penting dalam bidang bahan komposit hijau. Sifat kelesuan gentian daun nenas (PALF) yang diperkuat dengan komposit polilaktik asid (PLA) dikaji. Objektif kajian ini adalah untuk menganalisis kehidupan keletihan komposit PLA bertetulang PALF pada pemuatan serat yang berlainan dan memerhatikan moduli seketika, pelesapan tenaga dan permukaan patah lesu dengan menggunakan mikroskop imbasan elektron (SEM). Dalam kajian ini, serat daun nenas (PALF) digunakan sebagai spesimen manakala PLA digunakan sebagai matriks. Tujuan kajian ini adalah untuk menilai sifat kelesuan PALF bertetulang PLA dalam keadaan ketegangan. Spesimen dengan beban serat yang berbeza iaitu 40wt% dan 70wt% adalah kitaran kepada beban ketegangan tegangan ketegangan pada nisbah tegasan 0.1 pada frekuensi 2Hz. Sifat kekerapan untuk menentukan umur keletihan diberikan dua tahap tekanan; 50% dan 75% kekuatan tegangan muktamad dan keluk kerosotan kekakuan telah diplot. Pada 50% UTS, bilangan kitaran untuk 40% berat dan komposit PALF 70% adalah 23966 dan 597532 masing-masing. Sementara tahap stres yang lebih tinggi (75% UTS), bilangan kitaran untuk komposit 40 wt.% Dan 70 wt.% masing-masing adalah 5410 dan 5286. Kekuatan kelelahan komposit adalah lebih tinggi pada kandungan serat yang lebih tinggi yang menunjukkan bahawa kehidupan keletihan dapat ditingkatkan dengan menggunakan jumlah tetulang yang lebih tinggi. Tingkahlaku sifat komposit adalah matriks bergantung pada kandungan serat yang rendah (40% berat) dan serat bergantung pada kandungan serat yang lebih tinggi (70% berat). Analisis morfologi menunjukkan pull serat dan debonding berlaku semasa kegagalan.

ABSTRACT

Natural fibre reinforced polymer bio-composites constitute an important branch in the field of green composite materials. The fatigue life of pineapple leaf fibre (PALF) reinforced polylactic acid (PLA) composites is investigated. The objective of the study is to analyse the fatigue life of the PALF reinforced PLA composite at different fibre loading and observe the secant modulus, energy dissipation and fatigue fracture surface by using scanning electron microscope (SEM). In this study, pineapple leaf fibre (PALF) is used as specimen while PLA is use as the matrix. The purpose of this study is to evaluate the fatigue properties of the PALF reinforced PLA in tension-tension condition. The specimens with different fibre loading which are 40wt% and 70wt% are cycles to tension-tension fatigue loading at stress ratio 0.1 with 2Hz of frequency to determine the fatigue life at given two stress levels; 50% and 75% of ultimate tensile strength and the curves of stiffness degradation has been plotted. At 50% UTS, the number of cycle for 40 wt.% and 70wt% PALF composite are 23966 and 597532 respectively. While higher stress level (75 %UTS), the number of cycle for 40 wt.% and 70 wt.% composite are 5410 and 5286 respectively. The fatigue strength of the composite is higher at higher fibre content indicating that fatigue life could be improved by using higher amount of reinforcement. The facture behaviour of the composite was matrix depended at low fibre content (40 wt.%) and fibre dependent at higher fibre content (70 wt.%). Morphology analysis showed fibre pull out and debonding occurred during the failure

DEDICATION

This project is dedicated to

My beloved father, En.Norhaminudin Bin Mohd Nordin

My appreciated mother, Pn.Yuznita Bt Yoep Talib

Supportive friends

For giving me moral support, cooperation, encouragement and also understandings

Thank you So Much

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LIST OF ABBREVIATIONS

PALF	-	Pineapple Leaf Fibre
PLA	-	Polylactic acid
SEM	-	Scanning Electron Microscope
NaOH	-	Sodium hydroxide
ASTM	-	American Society for Testing and Materials.
rpm	-	Revolution per minute
PP	-	Polypropylene
PSB	-	Spersistent slip bands
GFRP	-	Glass fibre reinforced polymer
SED	-	Strain Energy Density
PBS	-	Polybutylene succinate
UTS	-	Ultimate Tensile Strength

LIST OF SYMBOLS

wt. %	-	Weight Percentage
° C	-	Degree Celsius
MPa	-	Mega Pascal
GPa	-	Giga Pascal
gr.	-	Grain
σ	-	Stress
%	-	Percent
g/cm3	-	Grams per centimeter cube
kg.cm3	-	Kilogram centimeter cube
Le	-	Embedded fiber length
kg	-	Kilograms
mm/min.	-	Millimeter per minute
ε	-	Tensile strain
σ	-	Tensile stress - Young's modulus
F	-	Force
A	-	Area stress

CHAPTER 1

INTRODUCTION

1.1 Background study

Environmental problems, sustainability concerns and an increasing awareness of the environment are forcing the current industry to look for new materials that are environmentally friendly. One of the factors contributing to the environmental problem, such as pollution, the increase in carbon footprint due to combustion activity, the worldwide lack of landfills increases in non- degradable plastic. Flax, sisal, kenaf, jute, bamboo, ramie, hemp and pineapple leaf fibre (PALF) are some of the most common natural fibres used as biodegradable reinforcement to produce composite materials. In light of this, natural fibres have received considerable attention as synthetic substitutes. It has its own properties and features that can benefit the composite. The main driving forces for new bio-composite materials are natural fibre costs, weight reduction and natural fibre recycling.

Now Malaysia is one of Asia's largest producers of pineapple as much as Hawaii. It produces an enormous amount of waste material, about 384,673 metric tons in 2008. The chemical composition of PALF is composed of holocellulose (70- 82%), lignin (5- 12 %) and ash (1.1%) (Asim et al., 2015). PALF has enormous mechanical properties and can be used in the production of polymer composites reinforced. Fibre length, matrix ratio and fibre arrangement depend on the physical and viscoelastic behaviour processing, tensile strength, flexural strength and impact. The main drawbacks of PALF are hydrophilic in nature; it does not connect well with the hydrophobic matrix, in particular at high temperatures. However, chemical treatments such as alkaline treatment with NaOH can be used to improve the quality between PALF and polymer. In addition, surface modification of sodium hydroxide (NaOH) chemicals can reduce water absorption and improve physical and mechanical properties.

Polylactic acid (PLA) is biodegradable and bioactive polyester made from the building blocks of lactic acid. PLA is manufactured from renewable sources and is compostable, addressing problems in solid waste disposal and lessening our dependence on petroleum-based raw materials. Most researchers agree that polylactic acid (PLA) is the most commonly used matrix because PLA is biodegradable and is made of renewable resources such as maize, starch and sugar cane. The PLA has a high resistance, good crease-rentation, grease and oil resistance and excellent aroma barrier properties. PLA degrade via hydrolysis process, trailed by biodegradation via bacteria producing lactic acid and carbon dioxide. However, the PLA is too fragile, low tensile elongation, low toughness and is not compatible with many packaging manufacturing processes. Therefore, in order to improve the properties of the PLA, natural fibre is often added as the reinforcement.

In this current study, experiments were performed on natural fibre reinforced thermoplastic composites under cyclic loading. The test involves for this study is tensile testing, fatigue testing and scanning electron microscope. The result of PALF-PLA testing discussed at the end of this study.

1.2 Problem Statement

Synthesis fibre such as carbon fibre, rayon, nylon, polyester, acrylic and etc. They are non-biodegradable which can never be dissolved with soil and threat to the environment damaging. Natural fibre which is pineapple leaf and poly-lactic acid are plant based. It is a sustainable resource, as it is renewable, biodegradable and carbon neutral and it can be used without damaging the environment. The stated component of the energy composite is normally subjected to the cyclic co-life. The composite will behave differently in static and dynamic condition. The fatigue properties of PALF reinforced PLA need to be investigated to ensure the structural integrity. At the same time most researchers tend to study and focus more on the static condition. Hence, the information and knowledge on dynamic condition is limited. Last but not least, it is to explore the advance application such as automotive field and medical field that are subjected to vibration and cyclic condition.

1.3 Objectives

The purpose of this project is to investigate the fatigue of pineapple leaf fibre reinforced polylactic acid composite. Thus, the objectives are:

1. To analyse the effect of the fibre loading onto the fatigue life of PALF reinforced PLA composite
2. To evaluate the change in fatigue characteristic of the PALF reinforced PLA composite using hysteresis diagram
3. To correlate the fracture surface with the fatigue behaviour of the PALF reinforced PLA composite

1.4 Scope of Research

The scope of this study is evaluate the fatigue strength of PALF reinforced PLA in tension- tension condition. Different fibre loading will be use (40 wt.% and 70 wt.% PALF). The fatigue test will be conducted at 2Hz cyclic frequency with sinusoidal waveform at loading ratio, R= 0.1 to evaluate their fatigue response, number of failure to cycle, secant modulus and energy dissipation will be evaluated. Tests involved tension –tension fatigue testing at 75 % and 50% of the Ultimate Tensile Strength. The surface fracture will be observed using scanning electron microscope (SEM).

1.5 Organization of Report

This report is all together divided into three chapters which are detailed as following. Chapter 1 is beginning with research background, problem statement, objectives and scope of research. Chapter 2 detailed literature surveys is presented on pineapple leaf fibre reinforced polymer composite, mechanical properties of natural fibre composites, fatigue behaviour of nature fibre composites. From this, the research gap is identified based on that, the research frame work and the objectives of the research work are presented. Chapter 3 deals about the methodology, proposed work, characterization technique, mechanical testing, tensile testing, fatigue testing. Preparation for the specimen, procurement of fibre, matrix and chemical used for this study are also discussed. Chapter 4 represents the results of the analysis of the PALF reinforced PLA composited. Chapter 5 presents the conclusion this study.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

People nowadays move towards a greener technology so they interested to find new sources to replace non-biodegradable material with other types of natural fibre such as jute, ramie, flax, bamboo, cactus, hemp, banana, oil palm fruit bunch. Natural Composite is a combination of two or more materials that differ in the form of a macro- scale composition. It can be adjusted to meet certain requirements and characteristics.

2.1 Natural Fibres

Natural fibres with their long records of serving mankind are very necessary in a wide range of applications and in the twenty- first century they compete and coexist with man-made fibres, especially since some distance such as quality, sustainability and the financial system of production are involved. According to Pickering et al., (2016), type, harvest time, method of extraction, factor ratio, cure and fibre content, matrix selection interface electricity fibre dispersion, fibre orientation, composite manufacturing process and porosity are the main elements affecting the overall mechanical performance of natural fibre composites. The classification of natural fibre is shown in Figure 2.1 and advantages of such natural fibres over ordinary fibres, such as glass and carbon, are demonstrated in Table 2.1.

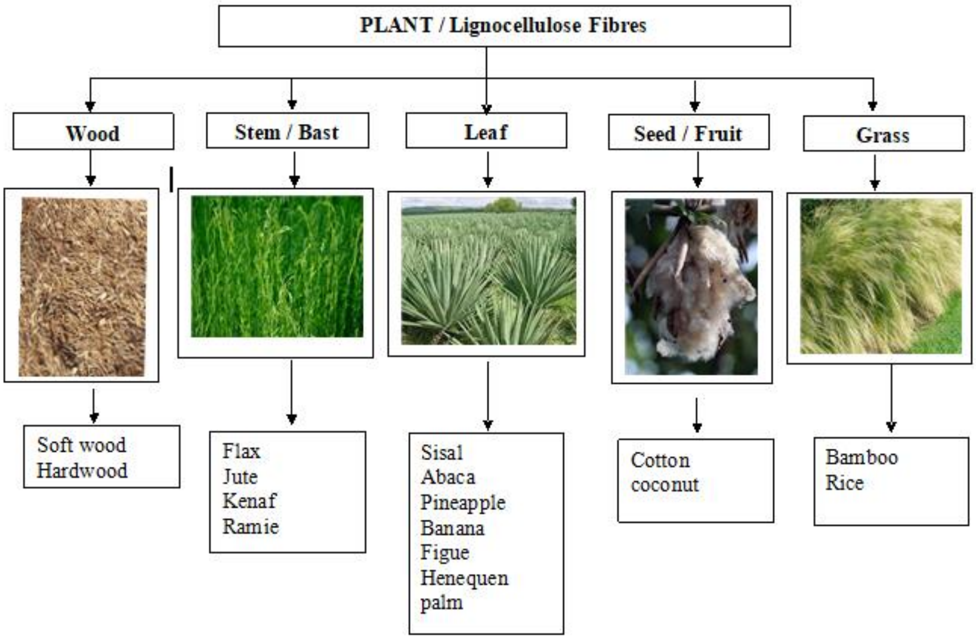

Figure 2.1: Classification of natural fibre

2.1.1 Properties of Natural Fibre

All natural fibres, except cotton, consist mainly of cellulose, hemicelluloses, lignin, waxes and several water- soluble compounds. The amount of cellulose in a given fibre determines its strength and stiffness provided by the hydrogen bonds and other cellulose bonds. Many factors affect the overall properties of fibres, from various production stages to the final processing stage. Many properties of natural fibres, especially mechanical properties, depend on the type of cellulose in the fibres, as the mechanical properties depend on the micro fibril angles, the degree of polymerization of cellulose and the total concentration of cellulose. Density, micro fibril angle, young module and elongation of fibres are some of the main variables that determine the overall properties of fibres. In addition, the properties of natural fibres depend on the plant's ecotype, maturity and location, as well as on the process of fibre extraction. (Siakeng et al.,2018)

Table 2.1: Physical and mechanical properties of natural fibre

Fibers	Density (g/cm^3)	Elongation (%)	Tensile strength (MPa)	Moisture absorption	Young's Modulus (GPa)
Cotton	1.5-1.6	3.0-10.0	287-597	8-25	5.5-12.6
Jute	1.3-1.46	1.5-1.8	393-800	12	10-30
Flax	1.4-1.5	1.2-3.2	345-1500	7	27.6-80
Hemp	1.48	1.6	550-900	8	70
Ramie	1.5	2.0-3.8	220-938	12-17	44-128
Sisal	1.33-1.5	2.0-14	400-700	11	9.0-38.0
Coir	1.2	15.0-30.0	175-220	10	4.0-6.0
Softwood	1.5	-	1000	-	40.0

2.1.2 Pineapple Leaf Fiber

According to Asim *et al*., (April, 2015), pineapple is a perennial herbaceous plant with a height and width of 1- 2 m belonging to the Bromeliaceae family. It is mainly grown in coastal and tropical regions and is often used for fruit purposes. In India, it is grown on 2250 acres of land and its production is constantly increasing. It is a fast stem with a dark green colour. The first leaf sprout looks decorative; it later turns into a 3 ft. long, 2 to 3 inch wide sword formed and severe spiral- organized fibrous leaf edges as well as curved in the direction of the passage area to keep the leaf stiff.

Repon *et al*.,(2017) reported that PALF has excellent mechanical properties between all natural fibres. Typically, PALF is made up of 10-82% cellulose, 5 - 12% lignin and 1.1% ash. The excellent mechanical behaviour is due to its high cellulose and low micro fibrillary angle.

a) Field of pineapple,

(b) Fruit of pineapple,

(c) Extraction of fibres from pineapple leaf

d) Dry PALF from pineapple leaf

Figure 2.2 : Production of pineapple leaf fibre, sequential (a) plantation of pineapple, (b) fruit of pineapple, (c) extraction of fibres from pineapple leaves, and (d) Indonesian PALF (Asim et al, 2015)

2.1.3 Mechanical Properties of Pineapple Leaf Fibre

Arib *et al*., (2006) studied the mechanical properties of the polypropylene composite reinforced by PALF. The PALF fraction volume was concentrated in this study. The composite PALF/polypropylene is made from a sandwich structure. The PALF/ polypropylene tensile module and tensile strength are increased by 687,02 MPa and 37,28 MPa. The bending properties of the composite also increased by 2.7 percent of the fibre volume fraction The bending properties of the composite also increased by 2,7 percent of the fibre volume fraction. For this study, it can therefore be concluded that the PALF / polypropylene composite. Table 2.3 shows the chemical composition of PALF cellulose, hemicellulose, alpha cellulose, lignin, pectin, ash and extractive as a chemical composition as possible. The mechanical properties of PALF are tabulated in Table 2.4.