UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FATIGUE BEHAVIOUR OF DEGRADABLE POLYLACTIC BASED NATURAL FIBRE COMPOSITE

Submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

TEY YIK YANG

B051610018

960413-01-6077

FACULTY OF MANUFACTURING ENGINEERING

2020

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **FATIGUE BEHAVIOUR OF DEGRADABLE POLYLACTIC BASED NATURAL FIBRE COMPOSITE**

Sesi Pengajian: **2019/2020 Semester 2**

Saya **TEY YIK YANG (960413-01-6077)**

mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☑ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Alamat Tetap:
11, Jalan S/P 6, Taman Sri Panchor,
83000 Batu Pahat,
Johor.

Tarikh: 1 JULY 2020

Disahkan oleh:

Cop Rasmi:
DR. ZALEHA BINTI MUSTAFA
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Tarikh: 20HB JULAI 2020

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FAKULTI KEJURUTERAAN PEMBUATAN
Tel: +606 – 270 2571 / Faks: +606 – 270 1047

Rujukan Kami (Our Ref) : UTeM.
Rujukan Tuan (Your Ref) :

Ketua Pustakawan
Perpustakaan Laman Hikmah
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya, 76100 Durian Tunggal
Melaka.

1 July 2020

Tuan/Puan,

PENGKELASAN LAPORAN PSM SEBAGAI SULIT/TERHAD LAPORAN PROJEK SARJANA MUDA KEJURUTERAAN PEMBUATAN: TEY YIK YANG

Sukacita dimaklumkan bahawa Laporan PSM yang tersebut di atas bertajuk "**Fatigue Behaviour of Degradable Polylactic Based Natural Fibre Composite**" mohon dikelaskan sebagai *SULIT / TERHAD untuk tempoh LIMA tahun dari tarikh surat ini.

2. Hal ini adalah kerana ianya merupakan projek yang ditaja sepenuhnya oleh Universiti Teknikal Malaysia Melaka (UTeM) dan hasil kajiannya adalah sulit.

Sekian dimaklumkan. Terima kasih.

Yang benar,

Tandatangan dan Cop Penyelia

DR. ZALEHA BINTI MUSTAFA
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

26/7/2019

DECLARATION

I hereby, declared this report entitled "Fatigue Behaviour of Degradable Polylactic Based Natural Fibre Composite" is the result of my own research except as cited in references.

Signature : .....

Author's Name : TEY YIK YANG

Date : 1 July 2020

APPROVAL

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

(Dr. Zaleha Binti Mustafa) – Signature & Stamp

DR. ZALEHA BINTI MUSTAFA
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

20/7/2019

ABSTRAK

Bahan komposit hijau mempunyai kelebihan berbanding komposit berasakan bahan tidak terurai dari segi kelestarian dan mesra alam. Komposit berasaskan bahan serat nenas dan polilaktid asid adalah bahan terurai sepenuhnya tanpa memberikan kesan kepada persekitaran. Tujuan kajian ini adalah untuk mengkaji sifat kelesuan komposit bahan polilaktik asid (PLA) bertetulang serat daun nanas (PALF) di bawah pembebanan berkitar. Objektif utama kajian ini adalah untuk melihat kesan jumlah kandungan bahan tetulang terhadap anggaran jumlah kitaran lesu dan sifat kerosakan yang berlaku di dalam komposit di bawah pembebanan berkitar. Bahan mentah PALF dirawat secara kimia sebelum proses fabrikasi. Komposit PALF / PLA kemudiannya dihasilkan dengan mengabungkan teknik *pre-pregging* dan mampatan panas. Spesimen dengan muatan serat 40 wt. % dan 70 wt. % PALF dibentuk dan dikenakan ujian kelesuan di dalam mod tegangan, pada nisbah tegangan 0.1 dengan frekuensi 4 Hz. Ujian kelesuan melalui kawalan beban sebanyak 50% dan 75% daripada kekuatan tegangan statik (UTS) bagi kedua-dua bahan komposit tersebut. Ujian kelesuan pada aras 25% UTS bagi komposit 40 wt. % PALF / PLA turut dilakukan untuk mengenal pasti had lesu. Sifat mekanikal kelesuan komposit dianalisa menggunakan gambarajah S-N, analisis keberangkalian Weibull, perubahan modulus sekan dan analisis pelesapan tenaga. Ujian lesu menunjukkan bahawa sifat rintangan kelesuan meningkat apabila kandungan bahan PALF meningkat dari 40 wt. % ke 70 wt. %, yang mana bilangan kitar lesu meningkat dari 183 266 kepada 700 631 kitaran. Pada aras beban rendah (25% UTS), bahan komposit telah mempamerkan kegagalan menunjukkan bahawa had lesu bahan adalah diaras lebih daripada 25% UTS. Pada aras beban yang lebih tinggi (70 % UTS), tenaga yang lebih besar terhasil. Modulus sekan bagi 40 wt. % dan 70 wt. % PALF / PLA komposit meningkat mengikut kitar lesu disebabkan oleh fenomena pengukuhan. Kerosakan dalaman komposit didapat telah bermula seawal kitaran ke-1000. Analisis Weibull menunjukkan bahawa tingkah laku kegagalan komposit bergantung pada komposisi serat yang digunakan, yang mana nilai kerosakan yang lebih besar (α) diperhatikan di dalam komposit yang memiliki kandungan serat yang lebih rendah (40 wt. % PALF).

ABSTRACT

Green composites using two or more degradable materials as reinforcement or matrix were promising as non-biodegradable composites substitutes due to their recyclability and sustainability. The aim of this study was to investigate the fatigue behaviour of pineapple leaf fibre (PALF) reinforced polylactic acid (PLA) composite under a cyclic loading. The objective of the study was to compare the effect of fibre loading onto the fatigue life of PALF/PLA composite and to evaluate the damage behaviour of the fatigued PALF/PLA composite. PALF was chemically treated prior to the fabrication process. The PALF/PLA composite was then produced by combination of pre-pregging technique and hot compression moulding. The specimens with fibre loading of 40 wt. % and 70 wt. % were cycled to tension-tension fatigue loading at stress ratio of 0.1 with 4 Hz frequency. The fatigue tests were conducted in load control at 50% and 75% of the ultimate tensile strength of the 40 wt. % and 70 wt. % PALF/PLA composite. For 40 wt. % PALF/PLA composite, lower stress level (25% UTS) was carried out in order to identify the fatigue limit of the composite. The fatigue life was recorded using S-N diagram, probability of the failure using Weibull analysis while their damage behaviour were evaluated using the secant modulus and energy dissipation analysis. The fatigue test showed as fibre loading increased from 40 wt. % to 70 wt. %, their fatigue life was increased from 183 266 cycles to 700 631 cycles respectively. At low stress level used (25% UTS) no run out was observed, indicated that fatigue endurance of this composite is beyond the 25% UTS. At higher stress level, larger dissipated energy was generated for both 40 wt. % and 70 wt. % PALF/PLA composite. The secant modulus of both 40 wt. % and 70 wt. % PALF/PLA composite was increased as the cycle progress due to stiffening effect. The internal damage has occurred after 1000 cycles in both of the composites. Weibull Analysis indicated that the failure behaviour of the composite was depending on the fibre loadings, because a larger damage value (α) is observed at lower fibre loading composite.

DEDICATION

This report is dedicated to my beloved parents,
who educated me and enable me to reach this level.
To my honoured supervisor,
Dr. Zaleha Binti Mustafa
for her advices, support and patience during completion of this project
and to all staffs & technicians,
for their advices and cooperation to complete this project.
Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

First and foremost, I would like to thank my supervisor, Dr. Zaleha Binti Mustafa. She had given me so much knowledge, guiding me and giving me so many beneficial lessons that I will be able to use in my future. She is always concern of my well-being. She has shown me that it takes dedication and perseverance to get this study done.

I would also like to thank my family and friends, who always giving me support and encourage me all the time. Apart from that, I would like to thank all the lecturers and staffs in the Fakulti Kejuruteraan Pembuatan. They assisted me and guided me throughout this semester to get this work done. Last but not least, I would like to thank Universiti Teknikal Malaysia Melaka for providing me this platform to allow me to complete my final year project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PALF	-	Pineapple leaf fibre
PLA	-	Polylactic acid
SEM	-	Scanning Electron Microscope
NaOH	-	Sodium hydroxide
ASTM	-	American Society for Testing and Materials
UTS	-	Ultimate tensile strength
PP	-	Polypropylene
PBS	-	Polybutylene succinate
GFRP	-	Glass fibre reinforced polymer
FTIR	-	Fourier transform infrared
PBAT	-	Polybutyrate adipate terephthalate

LIST OF SYMBOLS

wt. %	-	weight percentage
°C	-	Degree Celsius
MPa	-	Mega Pascal
GPa	-	Giga Pascal
ε	-	Tensile strain
σ	-	Tensile stress

LIST OF SYMBOLS

wt. %	-	weight percentage
°C	-	Degree Celsius
MPa	-	Mega Pascal
GPa	-	Giga Pascal
ε	-	Tensile strain
σ	-	Tensile stress

CHAPTER 1

INTRODUCTION

1.1 Background of study

The environmental friendly materials have received significant interest in recent years, in particular due to the increase in environmental consciousness, expanding worldwide waste issue and unsustainable consumption of petroleum. Therefore, the utilization of natural fibres in polylactic based composites have been attracting great interest because of its good properties compared to man-made fibres in term of relatively low weight, low cost, comparable mechanical properties and more sustainable. Natural fibres are mainly sourced from plants and animals. Bamboo, jute, flax, hemp, sisal, kenaf and pineapple leaf fibres (PALF) are most common and commercially natural fibres used as biodegradable reinforcement to fabricate bio-composite materials.

Poly (lactic acid) (PLA) is a compostable biopolymer which can be obtained from renewable sources such as sugarcane or corn starch. Since PLA meet many of the environmental requirements, most items that do not require high quality can be manufactured easily, such as food packaging, plastic bags, disposable cutlery and cups. Polylactic polymers are stiff and brittle materials and therefore plasticizers often be used to enhance their mechanical properties. The PLA is completely biodegradable. Their degradation occurs through lactic acid hydrolysis, which is metabolized by micro-organisms to water and carbon monoxide. Biodegradation occurs within two weeks by composting together with other biomass and the materials will completely disappear within 3-4 weeks (Oksman et al., 2003). Nevertheless, its poor mechanical properties and higher cost compared to petroleum based polymers restrict the usage of PLA.

PALF is commonly grown in Malaysia as well as Asia showing its great potential to be commercialized because of its high accessibility. The main chemical constituents compose of lignin (5-12%), cellulose (70-82%) and ash (1.1%) (Asim et al., 2015). Among various natural fibres, PALF has a higher tensile strength and modulus with 1627MPa and 82.5GPa respectively due to its higher cellulose content (Akil et al., 2011). PALF is currently a waste product of pineapple cultivation. Thus, it can be obtained for industrial purposes without any additional cost input. They were obtained by retting from the leaves of the plant Ananas comosus, the Latin name for the PALF belong to Bromeliaceae family. PALF is not as strong as synthetic fibre but it is biodegradable, low cost and low density which available as substitutes for the non-degradable and expensive synthetic fibre.

A bio-composite consists of two or more degradable materials as reinforcement or matrix to enhance their properties. It provides sustainability and environmental preservation because of its biodegradability. Bio-composite reinforced materials are widely accepted in place of traditional high strength materials and several light weight applications. These composite materials showing high tensile and flexural strength, good strength by weight ratio, high creep resistance and high compactness. However, most of this study is focused on the static condition while the cyclic behaviour is still limited. The composite will behave differently in static and dynamic condition. Thus, the main objective of this study is to evaluate their fatigue behaviour.

1.2 Problem Statement

The disposal of non-biodegradable composite after their intended life time has brings a huge environmental issue, raise the demand of the use of environmentally materials. Green composites using degradable materials as reinforcement or matrix are promising as non-biodegradable composites substitutes due to their recyclability and sustainability. Moreover, the demand and application of natural fibre composites are growing recently due to their comparable mechanical properties to the synthetic fibre composites but these composites face a major challenge in structural applications due to their fatigue performance under various load conditions. Materials are break at their ultimate tensile strength during the tensile test. However in reality, fatigue failure of structural materials are always occurs below the static strength of that material (Haque et al., 2019). There is not much information

PALF is commonly grown in Malaysia as well as Asia showing its great potential to be commercialized because of its high accessibility. The main chemical constituents compose of lignin (5-12%), cellulose (70-82%) and ash (1.1%) (Asim et al., 2015). Among various natural fibres, PALF has a higher tensile strength and modulus with 1627MPa and 82.5GPa respectively due to its higher cellulose content (Akil et al., 2011). PALF is currently a waste product of pineapple cultivation. Thus, it can be obtained for industrial purposes without any additional cost input. They were obtained by retting from the leaves of the plant Ananas comosus, the Latin name for the PALF belong to Bromeliaceae family. PALF is not as strong as synthetic fibre but it is biodegradable, low cost and low density which available as substitutes for the non-degradable and expensive synthetic fibre.

A bio-composite consists of two or more degradable materials as reinforcement or matrix to enhance their properties. It provides sustainability and environmental preservation because of its biodegradability. Bio-composite reinforced materials are widely accepted in place of traditional high strength materials and several light weight applications. These composite materials showing high tensile and flexural strength, good strength by weight ratio, high creep resistance and high compactness. However, most of this study is focused on the static condition while the cyclic behaviour is still limited. The composite will behave differently in static and dynamic condition. Thus, the main objective of this study is to evaluate their fatigue behaviour.

1.2 Problem Statement

The disposal of non-biodegradable composite after their intended life time has brings a huge environmental issue, raise the demand of the use of environmentally materials. Green composites using degradable materials as reinforcement or matrix are promising as non-biodegradable composites substitutes due to their recyclability and sustainability. Moreover, the demand and application of natural fibre composites are growing recently due to their comparable mechanical properties to the synthetic fibre composites but these composites face a major challenge in structural applications due to their fatigue performance under various load conditions. Materials are break at their ultimate tensile strength during the tensile test. However in reality, fatigue failure of structural materials are always occurs below the static strength of that material (Haque et al., 2019). There is not much information

that focus on the dynamic condition of natural fibre composite. Study of material fatigue behaviour is therefore critical for safe fatigue design especially in long-term applications. Haque et al. (2019) reported that the higher tensile strength of material exhibit a higher fatigue resistance but this is only true at high cyclic stress and the tensile strength of the material is less significant at low cyclic stress. A study by Abdullah et al. (2012) showed that the fatigue life a material is affected by the fibre loading but it showed less improvement at high cycle loading however the details of their failure behaviour is scarcely available. Thus, this study will focus changes in the composites integrity during the fatigue condition in order to shed some light on fatigue failure behaviour in natural fibre based composite at different fibre loading and stress amplitude.

1.3 Objectives

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

1. To compare the effect of fibre loading onto the fatigue life of PALF/PLA composite
2. To evaluate the damage behaviour of the fatigued PALF/PLA composite

1.4 Scope of Research

The scope of this study is evaluate the fatigue strength of PALF/PLA composite in tension-tension condition. Two fibre loadings will be used (40 wt. % and 70 wt. % PALF). The fatigue test will be conducted at 4Hz cyclic frequency with sinusoidal waveform at loading ratio, R=0.1 in tension-tension fatigue control. The test will carried out in load control stress amplitude of 50% and 75% of the ultimate tensile strength of the 40 wt. % and 70 wt. % PALF/PLA composite. For 40 wt. % PALF/PLA composite, lower stress level (25% UTS) will also be carry out in order to identify the fatigue limit of the composite. The number of cycles to failure, force and displacement will be recorded. The fatigue life will be recorded

using S-N diagram, probability of the failure using Weibull analysis while their damage behaviour will be evaluated using the secant modulus and energy dissipation analysis.

1.5 Organization of Report

This report contains five chapters included introduction, literature review, methodology, result and discussion, and conclusion.

Chapter 1 give details about the background of the study and the identified problem of the study. This is followed by objectives to be achieved throughout the study and scope which narrows down the area of the study. The important of the study and organization of report also include in this chapter.

Chapter 2 detailed literature review from journal articles and other scientific sources regarding the pineapple leaf fibre reinforced polymer composites, fatigue behaviour of natural fibre composites and mechanical properties of natural fibre composites.

Chapter 3 covers the methods applied to prepare sample preparation, characterization using quasi static tensile, fatigue testing and Weibull analysis.

Chapter 4 shows the discussion for the results obtained from all the testing from chapter 3. It show the analysis of the PALF reinforced PLA composite.

Chapter 5 shows the conclusion of this study and the recommendation which can be considered in the future research.