



# **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

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

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

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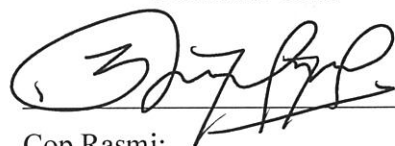
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## DECLARATION

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.

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## 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:



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## ABSTRAK

Bahan komposit hijau mempunyai kelebihan berbanding komposit berasaskan 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 polilaktid asid (PLA) bertetulang serat daun nenas (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 menggabungkan 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 pelepasan 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 ( $\alpha$ ) 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 ( $\alpha$ ) 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.

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# TABLE OF CONTENTS

ABSTRAK	i
ABSTRACT	ii
DEDICATION	iii
ACKNOWLEDGEMENT	iv
TABLE OF CONTENTS	v
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF ABBREVIATIONS	xii
LIST OF SYMBOLS	xiii
<b>CHAPTER 1: INTRODUCTION</b>	<b>1</b>
1.1 Background of Study	1
1.2 Problem Statement	2
1.3 Objectives	3
1.4 Scope of Research	3
1.5 Organization of Report	4
<b>CHAPTER 2: LITERATURE REVIEW</b>	<b>5</b>
2.1 Introduction	5
2.2 Degradable Composite	5
2.2.1 Biodegradable Polymer as Matrix	6

2.2.2	Polylactic Acid (PLA)	8
2.2.2.1	Properties of PLA	8
2.2.2.2	Synthesis of PLA	9
2.2.2.3	Degradation of Polylactic Acid (PLA)	10
2.3	Natural Fibre	11
2.3.1	Properties of Natural Fibre	12
2.3.2	Pineapple Leaf Fibre (PALF)	13
2.3.3	Mechanical Properties of Pineapple Leaf Fibre	14
2.4	Mechanical Properties of the Natural fibre reinforced composite	15
2.4.1	Morphology Analysis	17
2.5	Introduction to Fatigue	18
2.5.1	Fatigue Mechanism	19
2.5.2	Fatigue Behaviour of Fibre Reinforced Composite	21
2.5.2.1	Stress to Number of Cycle to Failure (S-N curve)	21
2.5.2.2	Stress-Strain Hysteresis Loops	25
2.5.2.3	Dynamic Modulus Evolution	27
2.5.2.4	Fracture Morphology under Fatigue Loading	28
<b>CHAPTER 3: METHODOLOGY</b>		31
3.1	Introduction	31
3.2	Flow Chart	31
3.3	Raw Materials Preparation	33
3.3.1	Polylactic Acid	33
3.3.2	Pineapple Leaf Fibre (PALF)	33
3.3.3	Sodium Hydroxide (NaOH)	34

3.3.4	Chloroform	34
3.3.5	Acetone	34
3.3.6	Acetic Acid	35
3.4	Sample Preparation Method	35
3.4.1	Alkaline Treatment	35
3.4.2	Pre-pregging	35
3.4.3	Hot Compression	36
3.5	Mechanical Testing	38
3.5.1	Tensile Testing	38
3.5.2	Fatigue Test	39
3.6	Weibull Distribution Analysis	40
 <b>CHAPTER 4: RESULTS AND DISCUSSION</b>		42
4.1	Results	42
4.1.1	S-N Curves	42
4.1.2	Stress-Strain Hysteresis Loops	44
4.1.3	Stiffness Evolution	48
4.1.4	Weibull Distribution	50
 <b>CHAPTER 5: CONCLUSION AND RECOMMENDATION</b>		52
5.1	Conclusion	52
5.2	Recommendation	53
5.3	Sustainable Design and Development	53
5.4	Complexity of the Study	54
5.5	Lifelong Learning	54

<b>REFERENCES</b>	55
<b>APPENDICES</b>	61
Gantt Chart for FYP I	61
Gantt Chart for FYP II	62

## LIST OF TABLES

2.1	Physical and chemical properties of PLA	9
2.2	Properties of natural fibres	13
2.3	Mechanical properties of pure epoxy and kenaf/epoxy reinforced composite	16
2.4	Impact test of PALF/epoxy composites	17
2.5	Bending test of PALF/epoxy composites	17
3.1	Properties of Polylactic Acid 6100D	33
3.2	ASTM Standard D638-02a	37
4.1	Hysteresis energy for 40 wt. % PALF/PLA composite at 25% UTS, 50% UTS and 75% UTS	45
4.2	Hysteresis energy for 70 wt. % PALF/PLA composite at 50% UTS and 75% UTS	45
4.3	Weibull parameter in fatigue test for 40 wt. % and 70 wt. % PALF/PLA Composite	51

## LIST OF FIGURES

2.1	Classification of Composite	6
2.2	Isomers of lactic acid	9
2.3	Direct polymerization of PLA	10
2.4	Ring-opening polymerization of PLA	10
2.5	Life cycle of PLA in nature	11
2.6	Classification of natural fibre	12
2.7	Extraction of pineapple leaf fibre	13
2.8	Tensile strength and modulus of PALF/PLA composites	15
2.9	Elongation at break of PALF/PLA composites	16
2.10	SEM micrographs of PALF/PLA composite at 40 wt. % PALF (a) PALF aggregation in composite (b) interphase between PALF and PLA	18
2.11	Fatigue damage mechanism (a) fibre breakage (b) matrix cracking and (c) interfacial shear failure	19
2.12	Fatigue life diagram of unidirectional composite	20
2.13	Stress-strain graph of unidirectional composite (a) low stiffness fibre and (b) high stiffness fibre composite	20
2.14	SN curve of epoxy	22
2.15	SN curve of sisal fibre composite	22
2.16	Sisal fibre composite after failure	22
2.17	SN-curve of kenaf/epoxy composites and glass/epoxy composite	23
2.18	SN-curves of FFRE and GFRE specimens	24
2.19	Residual tensile strength of jute/PLA composite	24
2.20	First and final hysteresis loop of flax/epoxy composite specimens	26
2.21	Evolution of hysteresis energy of flax/epoxy composite specimens	26
2.22	Stress-strain loops of jute/PLA composite	27
2.23	Evolution of dynamic modulus for GFRE and FFRE	28
2.24	Different fracture mechanism of composite	28
2.25	Macroscopic fracture morphology of jute/PLA composite (a) quasi-static tensile test (b) fatigue test at 80% of UTS (c) fatigue test at 50% of UTS	29

2.26	Microscopic fracture morphology of jute/PLA composite (a) quasi-static tensile test (b) fatigue test at 80% of UTS (c) fatigue test at 50% of UTS	30
2.27	Fracture surface right before fatigue failure (a) whole sample surface (b) area A without cracking (c) area B resin cracking (d) area C resin cracking and fibre breakage	30
3.1	Research flow chart	32
3.2	Pineapple leaf fibre yarn	34
3.3	Dried PALF/PLA pre-preg	36
3.4	Carver 30-12H Hot pressing machine	37
3.5	The dimension of tensile specimens of composite (ASTM Standard D638-02a)	37
3.6	DSES-1000 Universal Testing machine	39
3.7	EHF-LV20K2TV100NM-10 Servopulser	40
4.1	S-N curves of 40 wt. % and 70 wt. % PALF/PLA composite	43
4.2	S-N curve of 40 wt. % PALF/PLA composite at 25% - 75% stress amplitude	43
4.3	Hysteresis loops of 40 wt. % PALF/PLA composite at different amplitude level (a) 25% UTS (b) 50% UTS (c) 75% UTS	46
4.4	Hysteresis loops of 70 wt. % PALF/PLA composite at different amplitude (a) 50% UTS (b) 75% UTS	47
4.5	Secant modulus of 40 wt. % PALF/PLA composite at different amplitude levels	49
4.6	Secant modulus of 70 wt. % PALF/PLA composite at different amplitude levels	49
4.7	Weibull curve of 40 wt. % and 70 wt. % PALF/PLA composite	50
4.8	Failure probability of 40 wt. % and 70 wt. % PALF/PLA composite	51



## 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
$\varepsilon$	-	Tensile strain
$\sigma$	-	Tensile stress

## LIST OF SYMBOLS

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# 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

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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.