CHARACTERIZATION OF CONTINUOUS PINEAPPLE LEAF FIBRE REINFORCED POLYLATIC ACID COMPOSITE

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

by

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DECLARATION

I hereby, declared this report entitled "Characterization of Continuous Pineapple Leaf Fibre Reinforced Polylatic Acid Composite" is the result of my own research except as cited in references.

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Date : 22 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Engineering Materials) (Hons). The member of the supervisory committee are as follow:

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(Dr. ZALEHA BINTI MUSTAFA)

ABSTRAK

Gentian daun nanas (PALF) kaya dengan selulosa, murah dan mudah didapati mempunyai potensi sebagai komposit bertetulang. Dalam projek ini, kekuatan tegangan and modulus PALF sebagai tertulang kepada asid polylatic (PLA) disiasat. Permukaan PALF diubahsuai menggunakan rawatan akali bagi menigkatkan kelekatan diantara matrik.. Fourier transform infrared spectroscopy digunakan untuk mengenalpasti kewujudan natrium hidrosikda and penyingkiran 'pectin' dari permukaan gentian. Komposit PALF/PLA dihasilkan mengunakan pelbagai muatan yang berbeza (40 wt. %, 50 wt. %, 60 wt. % dan 70 wt. %) menggunakan teknik 'pre-pregging'dan acuan mampatan. Di samping itu, 1 wt. % CNT ditambah kedalam 70 wt.% komposit PALF/PLA untuk membandingkan pengaruh nanofiller terhadap sistem komposit. Ujian mekanikal menunjukkan kekuatan tegangan dan modulus pada tahap maksimum adalah 232.264 MPa dan 27.015 GPa diberi oleh 70 wt. % komposit PALF/PLA. Tambahan 1 wt. % CNT, meningkatkan lagi kekuatan tegangan dan modulus kepada 243.092 MPa dan 30.08 GPa. Kajian morfologi oleh Scanning Electron Microscopy (SEM) menunjukkan lekatan antara gentian and matrik yang baik walaupun peningkatan gentian yang tinggi adalh disebabkan oleh keberkesan penggunaan teknik 'pre-pregging'.

ABSTRACT

Pineapple leaf fibre (PALF) is rich in cellulose, relative inexpensive and abundantly available. In this project, tensile strength and modulus of PALF reinforced polylatic acid (PLA) is investigated. PALF surface modified is using alkaline treatment order to improve the wettability between matrix. Fourier transform infrared spectroscopy are confirm the present of sodium hydroxide and removal of pectin from the surface of the fibre. PALF/PLA composites is produced various fibre content (40 wt. %, 50wt%, 60 wt. % and 70 wt. %) using pre-pregging technique and compression moulding. In addition, 1 wt. % of CNT is added to 70 wt. % of PALF/PLA composites to compare the influence of nanofiller to the composites system. Mechanical testing shows the maximum tensile strength and modulus is 232.264 MPa and 27.015 GPa is given by 70 wt. % PALF/PLA composite. Addition of 1 wt. % of CNT, further increased their properties to 243.092 MPa and 30.08 GPa for tensile strength and modulus respectively. The fracture behaviour of the composites is investigated by using Scanning Electron Microscopy (SEM), shown the composites have good bonding between matrix and fibres even at high fibre loading due to the effective of pre-pregging approach.

DEDICATION

To my beloved parents,
Jamil Bin Abd Aziz
Nuraini binti Shafie

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First of all, in a humble way I wish to give all Praise to Allah, The Almighty God for with His Mercy has given me the strength and time to complete this report.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing And Materials
ABS	-	Acrylonitrile-butadine-sydrede
CNT	-	Carbon Nanotubes
DSC	-	Differential Scanning Calorimetric
DSF	-	Durian Skin Fibre
FTIR	-	Fourier Transform Infrared spcectra
HNT	-	Halloysite Nanotube
NaOH	-	Sodium Hydroxide
PALF	-	Pineapple Leaf Fibre
PLA	-	Polylactic Acid
PA6	-	Polyamide 6
PA11	-	Polyamide 11
PP	-	Polyproplene
ROP	-	Ring Of Polymerize
SEM	-	Scanning Electron Microscope
UTY	-	Untreated yarn
TY	-	Treated yarn

LIST OF SYMBOLS

%	-	Percent
g/cm^3	-	Grams per centimetre cube
wt. %	-	Weight percent
MPa	-	Mega Pascal
GPa	-	Giga Pascal
°C	-	Degree Celsius
kg.cm3	-	Kilogram centimetre cube
l_e	-	Embedded fibre length
kg	-	Kilograms
mm/min.	-	Millimetre per minute
ε	-	Tensile strain
σ	-	Tensile stress
E	-	Young's modulus
F	-	Force
A	-	Area

CHAPTER 1

INTRODUCTION

1.1 Background Study

The increasing of non-degradable plastic have contributed to the environment issue such as pollution, increase of the carbon footprint from the combustion process, landfill shortage around the world. This issue has been the motivation to the manufacturer and researcher to study and develop degradable materials that can be recycled or degrade naturally once they are no longer in the application, not only have outstanding degradability but compatible in mechanical strength with their non-degradable counterpart in order to be an economical alternative.

Biopolymer are normally derived from various natural botanical resources such as protein and starch, have been regarded as alternative material to petroleum based plastics because they are abundant, renewable, inexpensive and biodegradable (Liu et al. 2005). They contain oxygen or nitrogen atom in their chain structure, degrade by the act of microorganisms such as fungi, algae and bacteria thus part of natural cycle. Biopolymer can be classified as either naturally derived polymer or synthetic polymer, with wide range of mechanical properties and degradation rates that be utilised to suit the application. However, as like synthetic polymer, biopolymer may have shortcoming which restrict their use such as lower stiffness or degradation rate (Vieira et al. 2011)

Polylactic acid (PLA) is thermoplastic aliphatic polyester, a biopolymer type and commonly made up by the alpha-hydroxyl acids, which include polyglycolic acid or polymandelic acid, which make them biodegradable and compostable materials (Garlotta 2001). PLA possess high strength, 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. Nevertheless, the drawback of this polymer they are quite brittle, low toughness and has low tensile elongation. Therefore, in order to improve the properties of the PLA, natural fibre is often added as the reinforcement.

Natural fibre such as pineapple leaf fibre (PALF) has excellent mechanical properties and can be utilised as reinforcement in polymer composite. PALF fibre has multicellular and lignocellosic. PALF normally contained about 70-82 % cellulose, 5-12 % lignin and approximately 1.1 % ash (Asim et al. 2015). The superiority of their mechanical properties is possibly due to the high cellulose content (Arib, 2004). However, due to the hydrophilic nature of the natural fibre contribute to the weak interaction between the matrix/fibre interfaces when they are added in a more hydrophobic matrix such as PLA. Therefore, treatment and modification of the fibre is often adopted to improve their interaction. Another drawback in natural fibre composite is the utilising of fibre loading in the composite are often limited in comparison to their synthetic counterpart, due to lack of wettability cause by poor matrix flow in the fibre, thus limiting their mechanical range and application.

In this research, long PALF and nano-filler are used as the reinforcement elements in the PLA matrix to produce a fully degradable composite with possibly superior properties.

1.2 Problem Statement

The petroleum-derived plastic is often cause poor impact to the environment (Sujaritjun et al. 2013). The increasing in population contributed to the increasing production to suit our lifestyle and daily need, in which cause rise of domestic waste as well as consumer by product. Thus, poor waste management as well as shortage of landfill area has taking its toll to the environment. Based on Clean Malaysia.com, Malaysia has produced an average of 30,000 tons of waste in year 2015And only 5% of this is recycled. The country build-up of solid waste is resulting in tremendous land and air pollution, resulting in health problems for communities and bottlenecks to the economic growth. Thus, degradable composite that can be degraded by the nature such as natural fibre and degradable matrix is favourable to replace the synthetic materials in order to reduce the environmental issue. However, this bio composite is inferior in strength and their fibre loading often limits to less than 40 vol. % due to difficulty in achieving good adhesion between the fibre- matrix.

Thus, in this study, attempt to improve the mechanical strength of the PALF-PLA composite will be taken by increasing the fibre content and using long continuous fibre. In order to overcome the wettability problem of the fibre-matrix at higher fibre loading, the distance of the matrix to fibre will be decreased by adopting pre-pregging method.

1.3 Objectives

The objectives of this project are:

a) To compare the effect of different fibre loading (wt. %) on the mechanical properties of the PALF-PLA composite.
b) To evaluate the effect of the filler addition (wt. %) on the mechanical properties of PALF-PLA composite.
c) To relate fracture behaviour of the PALF-PLA composite using morphological analysis

1.4 Scope

The scope of this study is evaluate the mechanical strength of the PALF loading (40,50,60 and 70 wt. %) in PLA matrix as well as the effect addition of nano-filler into the matrix system. 1 wt. % of carbon nano tube (CNT) is used this study. The fabrication of the composite will be carried out through pre-pregging technique and compression moulding. Characterization of the composite will be carried out using DSC, FTIR, SEM and tensile testing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Composite is a combination of two or more materials, differing in form of composition on a macro-scale. It can be tailor to meet the certain requirement and properties.

2.2 Natural Fibre

Bio-based composite in more precise way by refer to natural fibre reinforced composite. Due to environmental issue as well as increase in price of petroleum base synthetic fibre, the focus of the polymer composite now is shifting to utilize natural fibre as reinforcing components with polymer. The advantages of these natural fibre over traditional reinforcing fibres such glass and carbon are shown in Table 2.1. According to Pickering et al. (2016), the main factor affecting mechanical performance of natural fibre composites are fibre selection which are includes type, harvest time, extraction method, aspect ratio, treatment and fibre content, matrix selection interfacial strength fibre dispersion, fibre orientation, composite manufacturing process and porosity.

Cellulose based fibre can be classified to wood fibre and non-wood fibres (Figure 2.1). For the non-wood fibre, they can be further classified into straw, plant (such bast, leaf and seeds) and grass. PALF is a plant leaf fibre.

Table 2.1: The Advantages and Disadvantages of Natural Fibre (Pickering et al. 2016)

Advantages	**Disadvantages**
Low density and high specific strength and stiffness	Lower durability than for synthetic fibre composites but can be improved considerably with treatment
Fibre are renewable resource, for which production requires little energy involve CO_2 absorption whilst returning oxygen to the environment	High moisture absorption which resulting swelling
Fibre can be produced at lower cost than synthetic fibre	Lower strength, in particular impact strength compared to the synthetic fibre composites
Low hazards manufacturing process	Greater variability of properties
Low emission of toxic fumes when subjected to heat and during incineration at end of life	Lower processing temperatures limiting matrix option.
Less abrasive damage to processing equipment compared with that for synthetic fibre composites.	

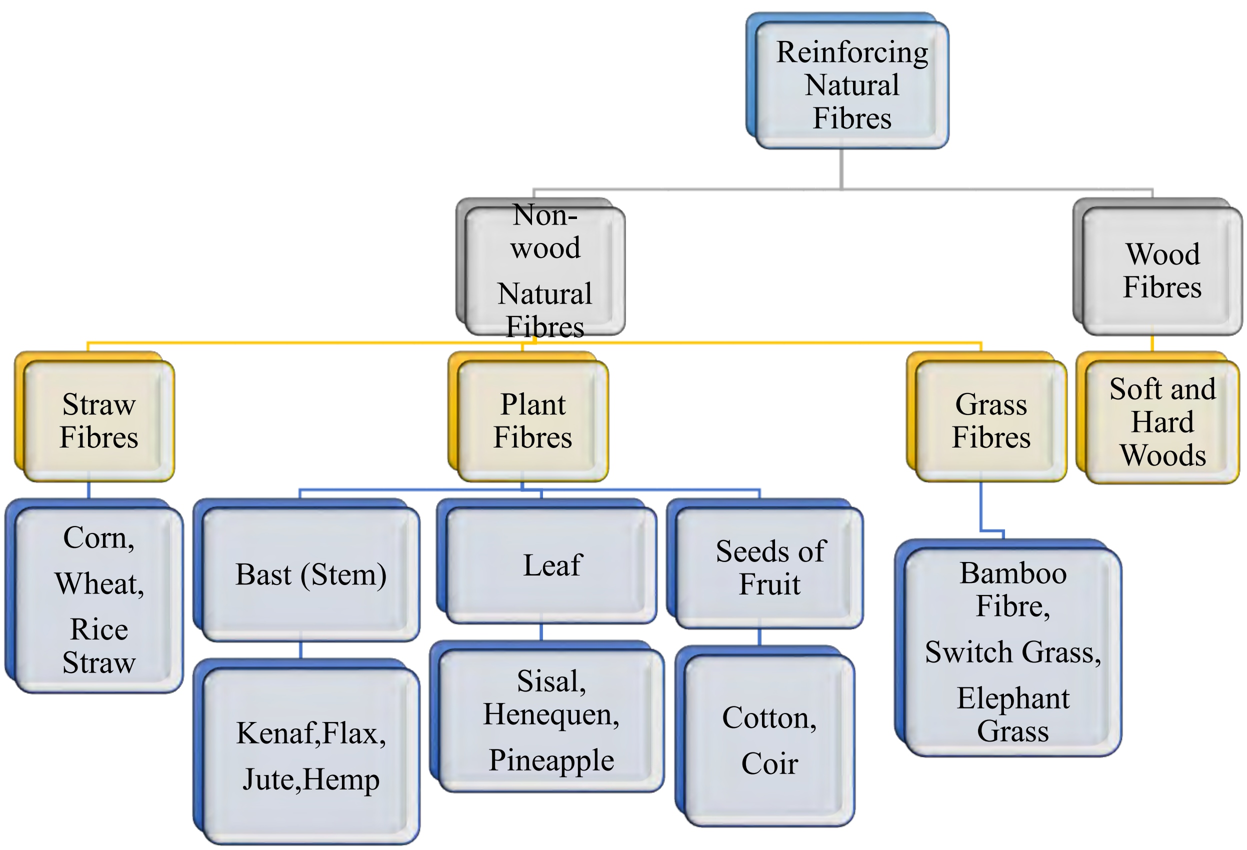


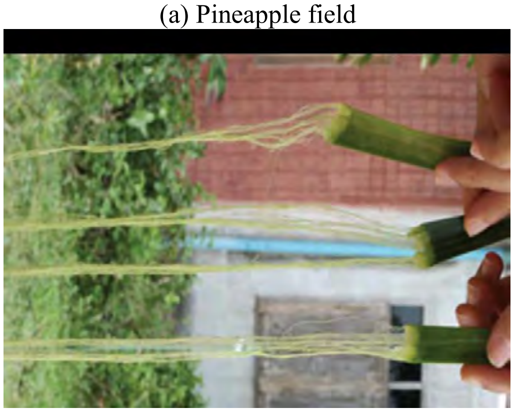
Figure 2.1: Categories for Natural Fibre

2.3 Pineapple leaf fibre (PALF)

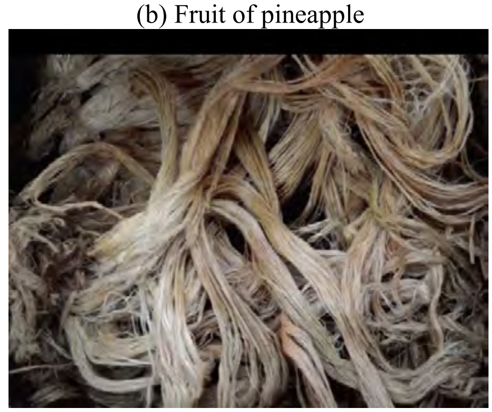
Pineapple is perennial herbaceous plant with 1 until 2 m for both height and width. It belongs to family of Bromeliaceous. It is chiefly cultivated in coastal and tropical regions, mainly for its fruits purpose. In India, it is cultivated on about 2250 000 acres of land and is continuously increasing its production. Pineapple plant has a short stem with dark green colour. (Figures 2.2a and 2.2b). Their first sprout of leaf looks decorative, in which later can grow up to 3 feet long, with 2 to 3 inch wide sword shaped leaves edges. Productions of Pineapple leaf fibres are plentiful for industrial purpose, they are easy produce, renewable and available supply. (Asim et. al,2015)

(a) Pineapple field

(b) Fruit of pineapple



(c) wet pineapple leaf fibres



(d) dry PALF from pineapple leaves

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)

2.3.1 Structure and Processing of PALF

Asim et al. (2015) reviewed that PALF is made out of numerous chemicals constituents. It is multicellular lignocellulosic fibre containing polysaccharides, lignin in real sum, and some excavator chemicals like fat, wax, pectin, uronic corrosive, and anhydride, pentosane, shading colour, inorganic substance and other. The fibre is normally fine is size, and has little multicellular strands like a string. These cells are firmly joined with the assistance of pectin. PALF constitute cellulose (70–82 %) similarly in cotton (82.7 %). PALF has superior mechanical quality over the jute and often is utilized in form of fine yarn. The cellulosic atoms model in the PALF is a three-dimensional structure and parallel to crystalline area of the fibre. PALF is has regular shape, and has stiffness modulus, flexural and torsional unbending nature as much as jute strands.

2.3.2 Surface treatment of PALF

The development of the natural fibre is not progress as fast as their synthetic competitor due poor moisture resistance and low mechanical properties. PALF, as any other natural fibre is hydrophilic materials, while most polymeric matrix is hydrophobic. Thus it pose a challenge in their unison during the fabrication. In order to overcome this issue, proper modification on their surface must be carried out. Surface treatment of the crude normal fibre can be carried out using acetylation, blanching, joining, mercerization, oxidation, plasma treatment and scouring method (Sheikh Md Fadzullah and Mustafa, 2016).

Panyasart et al. (2014) studied the effect of surface treatment on the mechanical and thermal properties of pineapple leaf fibre (PALF) reinforced polyamide 6 composite. In this study, PALF were alkaline treated using 5 wt. % NaOH and 5 wt. % saline treatment. The composite were compared and showed the mechanical properties for PALF that undergoes saline treatment is higher than the alkaline treatment. The crystallinity of treated fibre is thought to be reduced and closer to the crystallinity of the polyamide 6, thus suggesting that they contribute to the strong interfacial interaction that occurred.

Threepopnatkul et al. (2012) reported the influence of different surface treatment of PALF reinforced Acrylonitrile-butadiene-styrene (ABS) matrix. The PALF fibre was pre-treated with 2 wt. % sodium hydroxide (NaOH) together with 1 wt. % of cellulose enzyme treatment and 0.5 wt. % of saline treatment. In this report, composite were compared and show the tensile strength of the saline treated composite is higher than the cellulose enzyme treatment. It also showed that the composite that were treated with NaOH and cellulose enzyme also has higher Young's modulus than just treated with the NaOH.

2.3.3 Chemical Composition of PALF

Table 1 show the chemical composition in the PLAF cellulose, hemicellulose, alpha cellulose, lignin, pectin, ash and extractive as possible chemical composition.

Table 2.2: The Chemical Composition of PLAF (Devi et al.,(1996), Arib et al.,(2004), Jaramillo et al.,(2016))

Cellulose content (%)	Hemicellulose (wt. %)	Lignin content (wt. %)	Pectin (wt. %)	Moisture content (wt. %)	Extractives	Ash (%)	PALF Composition
70-80	-	5-12	-	-	-	1.1	Devi et al.,1996
70-80	-	5-12	-	-	-	1.1	Arib et al.,2004
66.74	17.45	8.31	-	9.40	6.49	0.71	Jaramillo et al.,2016

2.3.4 Mechanical Properties of PALF

The mechanical properties of PALF is tabulated in Table 2.

Table 2.3: Mechanical properties of PALF

Properties	Jaramillo et al., 2016	Arib et al. , 2006	Devi et al., 1996
Tensile strength (MPa)	413-1627	126.60	170
Young's Modulus (MPa)	125	4405	6210
Elongation at break (%)	0.8-1	2.2	3