UNIVERSITI PUTRA MALAYSIA

MECHANICAL PROPERTIES OF OIL PALM FIBRE-THERMOSET COMPOSITES

MOHD ZUHRI MOHAMED YUSOFF

MECHANICAL PROPERTIES OF OIL PALM FIBRE-THERMOSET COMPOSITES

MOHD ZUHRI MOHAMED YUSOFF

MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA

2009

MECHANICAL PROPERTIES OF OIL PALM FIBRE-THERMOSET COMPOSITES

By

MOHD ZUHRI MOHAMED YUSOFF

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

April 2009

DEDICATION

My father, Mohamed Yusoff Mohd Noor

My mother, Suriah Abdul Rahman

My siblings, Mohd Zohdi Mohamed Yusoff

Mohd Zafri Mohamed Yusoff

Mohd Zurmi Mohamed Yusoff

Nurza Mohamed Yusoff

Mohd Zuhir Mohamed Yusoff

Aisyah Mohamed Yusoff

Mohd Zufar Mohamed Yusoff

and

My love, Zafirah Salim

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

MECHANICAL PROPERTIES OF OIL PALM FIBRE-THERMOSET COMPOSITES

By

MOHD ZUHRI MOHAMED YUSOFF

April 2009

Chairman : Professor Ir. Mohd Sapuan Salit, PhD

Faculty : Engineering

Over the last decade, polymers reinforced with natural fibres composites have been getting an increasing attention from the academic world and various industries. Natural fibres are prospective reinforcing materials and their usage until now has been more traditional than technical. The attractive features of natural fibres are their low cost, lightweight, high specific modulus, renewability and biodegradability. Oil palm empty fruit bunches (OPEFB) are readily available in large quantities in palm oil mills. The fact is oil palm fibre (OPF) can be obtained directly from natural resource, cheap and also has advantages due to their renewable nature, low cost, and easy availability. This study was aim to determine the tensile and flexural properties of oil palm fibre-thermoset composites. Oil palm fibre/phenol formaldehyde (OPF/PF) composites and oil palm fibre reinforced epoxy (OPF/Epoxy) composites were fabricated to carry out the determination of mechanical properties. The composites were prepared by volume fraction of 40%, 50% and 60% for OPF/PF while for OPF/epoxy were 5%, 10%, 15% and 20%. Composites were cut based on

the ASTM D638 for tensile testing and ASTM D790 flexural testing. The testing was conducted on a Universal Testing Machine while the interfacial adhesion between fibre and matrix were observed using the scanning electron microscopy (SEM). Results from tensile and flexural tests of OPF/PF composites showed an increasing trend of tensile and flexural strengths as the volume fraction of fibre was increased. From the scattered values, it is found that the highest tensile and flexural strengths for OPF/PF composites were obtained at 60% volume fraction, in average. The results of tensile and flexural tests for OPF/Epoxy composites showed that by the addition of fibre content, the tensile and flexural strength was decreased compared to pure epoxy resin (0% fibre). It has been notice that to obtain the optimum tensile and flexural properties was found at the volume fraction of 5%. It is also found that the dispersion of fibre and interfacial adhesion between fibre – matrix can affect the mechanical properties of the composites.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

SIFAT MEKANIKAL KEPADA KOMPOSIT GENTIAN KELAPA SAWIT-TERMOSET

Oleh

MOHD ZUHRI MOHAMED YUSOFF

April 2009

Pengerusi : Professor Ir. Mohd Sapuan Salit, PhD

Fakulti : Kejuruteraan

Sejak sedekad yang lalu, polimer yang di perkuatkan dengan bahan komposit gentian semulajadi telah mendapat perhatian daripada dunia akademik dan pelbagai industri. Gentian semulajadi adalah bakal bahan penguat dan penggunaannya hingga sekarang lebih kepada tradisional daripada teknikal. Ciri-ciri menarik gentian semulajadi adalah kos yang rendah, ringan, modulus yang tinggi, boleh diperbaharui dan boleh terurai. Tandan buah kosong kelapa sawit (OPEFB) mudah di dapati dalam kuantiti yang besar daripada kilang-kilang minyak kelapa sawit. Secara fakta, gentian kelapa sawit (OPF) boleh diperolehi terus dari sumber asli, murah dan juga mempunyai kelebihan kerana sifat boleh diperbaharui, kos rendah, dan mudah di dapati. Tujuan kajian ini adalah untuk menentukan ciri–ciri ketegangan dan kelenturan komposit gentian kelapa sawit–thermoset. Komposit gentian kelapa sawit/fenol formaldehide dan gentian kelapa sawit bertetulang komposit epoksi telah di reka untuk penentuan sifat mekanikalnya. Komposit mengandungi pecahan isipadu 40%, 50% dan 60% di sediakan untuk OPF/PF manakala 5%, 10%, 15% dan 20% untuk OPF/Epoxy.

Komposit di potong berdasarkan ASTM D638 untuk ujian ketegangan dan ASTM D790 untuk ujian kelenturan. Ujian telah di buat dengan menggunakan mesin ujian universal manakala ikatan antara permukaan gentian dan matriks di perhatikan dengan menggunakan alat pengimbas mikro (SEM). Hasil daripada ujian ketegangan dan kelenturan bagi komposit OPF/PF menunjukkan trend peningkatan kekuatan ketegangan dan kelenturan apabila pecahan isipadu bertambah. Daripada nilai keputusan ujian yang rawak, di dapati kekuatan ketegangan dan kelenturan yang tertinggi bagi komposit OPF/PF diperolehi pada pecahan isipadu 60% secara purata. Keputusan ujian ketegangan dan kelenturan bagi komposit OPF/Epoxy pula menunjukkan dengan penambahan kandungan gentian, kekuatan ketegangan dan kelenturan menurun berbanding dengan epoksi tulen (gentian 0%). Daripada pemerhatian, untuk mendapatkan optimum ciri-ciri ketegangan dan kelenturan ianya di temui pada pecahan isipadu 5%. Ianya juga didapati bahawa taburan gentian dan ikatan antara permukaan gentian – matriks boleh memberi kesan pada ciri-ciri mekanikal bahan komposit.

ACKNOWLEDGEMENTS

First and foremost, I would like to extend my deepest praise to Allah S.W.T who has given me the patience, strength, determination and courage to complete this thesis.

I wish to express my sincere gratitude to my supervisor, Professor Ir Dr Mohd Sapuan Salit, for his guidance, encouragement, assistance, and counsel throughout the course of this study and in the preparation of this dissertation. Sincere appreciation is also extended to Associate Professor Datin Dr Napsiah Ismail for serving as my co-supervisor.

Sincere thanks are extended to Mr. Mohd Solah Deraman, Mr. Ridzuan Ramli, Mr. Zawawi Ibrahim and Mr. Rosli Ismail from Malaysia Palm Oil Board for helping in giving knowledge and ideas in doing this research and also making valuable suggestions. Special thanks to the Faculty of Engineering, staff, and fellow graduate students of the Department of Mechanical and Manufacturing Engineering for their assistance and friendship. I am also grateful to Universiti Putra Malaysia for giving the Graduate Research Fellowship (GRF) as financial support.

Special appreciation goes to my parents, Mohamed Yusoff Mohd Noor and Suriah Abdul Rahman, and my siblings for their patience, understanding, and encouragement. Thanks also to those who helped directly or indirectly during this research.

I certify that a Thesis Examination Committee has met on 14 April 2009 to conduct the final examination of Mohd Zuhri Mohamed Yusoff on his thesis entitled Mechanical Properties of Oil Palm Fibre-Thermoset Composites in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Shamsuddin Sulaiman, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Ir. Nor Mariah Adam, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Aidy Ali, PhD
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Md Mohafizul Haque, PhD
Professor
Department of Manufacturing and Materials Engineering
Faculty of Engineering
International Islamic University of Malaysia
(External Examinar)

BUJANG KIM HUAT, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia.

Date: 21 May 2009

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

Ir. Mohd Sapuan Salit, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Napsiah Ismail, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

HASANAH MOHD GHAZALI, PhD
Professor and Dean
School Of Graduate Studies
Universiti Putra Malaysia

Date: 8 June 2009

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

MOHD ZUHRI MOHAMED YUSOFF

Date: 11 May 2009

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOMENCLATURE

ABBREVIATIONS

ASTM	American Society for Testing and Materials
BPFR	Boron-containing phenol-formaldehyde resins
CF	Carbon fibres
DPL	Date palm leave
EFB	Empty fruit bunch
FTIR	Fourier Transform Infra-Red
GF	Glass fibre
MAH	Maleic anhydride
MDF	Medium density fibreboard
MPOB	Malaysian Palm Oil Board
NFC	Natural fibre composites
OH	Hydroxyl
OPEFB	Oil palm empty fruit bunch
OPF	Oil palm fibre
OPF FM	Oil palm frond fibre mat
OPFBF	Oil palm fruit bunch fibre
PF	Phenol formaldehyde
PKC	Palm kernel cake
PMCs	Polymer matrix composites
PP	polypropylene
PU	Polyurethane

PVC-U	Unplasticised poly (vinyl chloride)
ROM	Rule of mixture
SEM	Scanning electron microscopic

SYMBOLS

ρ	Density (g/cm^3)
σ	Stress (MPa)
ε	Strain (mm/mm)
A	Cross section area (mm^2)
b	Width (mm)
d	Thickness (mm)
E	Young's modulus (MPa)
F	Force (kN)
L	Length (mm)
P	Load (N)
S_τ	Tensile strength (MPa)
T	Thickness (mm)
V	Volume of concentration (litre)
W	Weight (g)

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Over the last decade, polymers reinforced with natural fibres composites have been getting increased attention from the academic world and from the various industries. The rapid growth in the consumption of plastic products, persistence of plastic in the environment, the shortage of landfill space, the depletion of petroleum resources and entrapment by the ingestion of packaging plastic by marine and land animals have spurred the efforts to look for better alternatives (Khalid et al., 2008).

Fibre reinforced polymers especially with glass fibres, have been an importance in technical applications such as the automotive sector, where high mechanical properties and dimensional stability have to be combined with low weight. In the past, many researches have been made to investigate the suitability of natural fibres as a reinforcing component for thermoplastic and injection mouldable materials because of their low density and ecological advantages. They open up further possibilities in waste management as they are biodegradable and therefore can lead to highly functional composite materials if used in combination with biodegradable thermoplastic polymers (Wollerdorfer and Bader, 1998).

According to Mohanty et al. (2002), natural fibres likes kenaf, flax, jute, hemp, and sisal have attracted renewed interest to replace the artificial fibres such as carbon, aramid, and glass in the automotive industry. Natural fibres have a few advantages over the manmade fibres such as low cost, low density, acceptable specific strength properties, ease of separation, carbon dioxide sequestration, and biodegradability. The fibres act as reinforcement in the fibre-reinforced composites by giving strength and stiffness to the composite structure.

Scientists and technologists is now attracted to the natural fibres such as banana, cotton, coir, sisal and jute for the application in consumer goods, low-cost housing and other civil structures. These natural fibre composites are found to have a better electrical resistance, good thermal and acoustic insulating properties, and higher resistance to fracture. It has many advantages compared with the synthetic fibres such as low weight, low density, low cost, acceptable specific properties, recyclable and biodegradable. Beside, they are also renewable, have high strength and stiffness and cause no skin irritations. Natural fibres also have a few disadvantages, for example moisture uptake, quality variations and low thermal stability. Many investigations have been made on the potential of the natural fibres as reinforcements for composites and in several cases, the results have shown that the natural fibre composites own good stiffness but the composites do not reach the same level of strength as glass fibre composites (Oksman et al., 2003).

1.2 Problem statements

Various researches have been done on natural fibre composite from the past. The most commonly used natural fibre likes hemp, sisal, cotton, flax, coir, and jute are the fibres to reinforce polymers such as polystyrene, polyolefin, epoxy resins, and unsaturated polyester. Oil palm fibre/phenol formaldehyde (OPF/PF) and oil palm fibre reinforced epoxy (OPF/epoxy) composites is still not been studies widely. The fact is oil palm fibre can be obtained directly from natural resource, cheap and also has advantages due to their renewable nature, low cost, and easy availability.

1.3 Significance of study

The potential of the abundant resources from forest will be used as a fibre in reinforcing the composite show the main significance of this study. Beside, oil palm fibre will lead to improve the performance qualities. This composite also has potential to be applied for the household application. This study is significant because there is a need to generate the idea, to evaluate and to try to explore the new natural resources with low production cost considering on to abundance and readily available material in Malaysian tropical forest.

1.4 Objectives

The objectives of this study are as follows:

i. To determine the effective ratio of oil palm fibre/phenol formaldehyde composites towards increasing tensile and flexural properties.
ii. To determine the effective ratio of oil palm fibre/epoxy composites towards optimum tensile and flexural properties.
iii. To determine the reason why the mechanical properties of composites is increased and decreased.

1.5 Scope of study

The scope of study is mainly focusing on the mechanical properties of oil palm fibre composites. It includes the determination of mechanical properties under tensile and flexural testing on the basis of ASTM standard D638-00 (2000) and ASTM standard D790-00 (2000) respectively. The morphological characteristics of oil palm fibre are also included in this study. This morphological aspect is important especially in evaluating the broken fibre and matrix after testing. Finally, the relationship between fibre and matrix was carried out from the broken samples.

1.6 Structure of thesis

Chapter 1 gives the background of studies, problem statements, significance of study, objectives including the scopes of the study. A literature review on previous research work in various areas which is relevant to this research is presented in Chapter 2. The literature started with a comprehensive literature survey on the mechanical properties of composite products made of natural fibres. A review of the mechanical properties of oil palm fibre is also included in this chapter.

The methodology of the study is described in Chapter 3. This chapter presents techniques to determine the mechanical properties of single oil palm fibre. It also includes the techniques of the preparation of composites and the determination of their mechanical properties.

Chapter 4 is the results and discussion on the mechanical properties of the single oil palm fibre, mechanical properties of oil palm fibre/phenol formaldehyde composites and mechanical properties of oil palm fibre reinforced epoxy composites. The mechanical properties under tensile and flexural tests have been analyzed and discussed in this chapter. Scanning electron microscopic (SEM) study was also included in this chapter. Finally, in chapter 5 the conclusions and recommendations for the further works have been presented.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Composites are materials made from two or more materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure.

Basically, fibre reinforced materials are composed by two elements which is fibre and matrix. Generally the fibre acts as the reinforcement of the matrix material or, alternatively the matrix acts as an adhesive between the fibres (Nazareth et al., 2001).

It consists of fibres with a high strength and modulus embedded in or bonded to a matrix with boundary between them. Both fibres and matrix will retain their physical and chemical identities and will come out a combination of properties that cannot be achieved with either of the elements acting alone (Mallick, 1993).

The function of the matrix in fibre-reinforced composites is to transfer stresses between fibres, to provide a barrier against an adverse environment and to protect the surface of the fibres from mechanical abrasion. The matrix just plays a minor role in the tensile load-carrying capacity of a composite structure (Mallick, 1993).