UNIVERSITI PUTRA MALAYSIA

MECHANICAL PROPERTIES OF ALKALI-TREATED SUGAR PALM (*ARENGA PINNATA*) FIBER REINFORCED EPOXY COMPOSITES

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2008

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DANDI BACHTIAR

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

May 2008

DEDICATION

My Father, Bachtiar Amin

My Mother, Alima

My Wife, Cut Helida

And

My Children, Muhammad Hadid Ghifary

Muhammad Salman Alfarisi

Siti Maghfira Azzahra

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 ALKALI-TREATED SUGAR PALM (*ARENGA PINNATA*) FIBER REINFORCED EPOXY COMPOSITES

By

DANDI BACHTIAR

May 2008

Chairman : Professor Ir. Mohd. Sapuan b. Salit, PhD

Faculty : Engineering

The aims of this study is to determine the mechanical properties (tensile, flexural and impact properties) of *Arenga pinnata* fiber reinforced epoxy polymer composite after introduce the alkali treatment to the *Arenga pinnata* fiber. The fiber was treated by alkali solution with 0.25 M and 0.5 M NaOH solution for 1 hr, 4 hrs, and 8 hrs soaking time. The fiber was mixed with with epoxy and hardener at 10% of volume with long random type of fiber arrangement. Hand lay up process in this experiments were to produce specimen test.

The mechanical properties of those fibers are 466.07 MPa for the tensile strength and 3.9 GPa for the modulus, the tensile strength of the pure epoxy is 69.39 MPa and 2.3 GPa for the modulus.

Results from the tests show that the improving mechanical properties of *Arenga pinnata* fiber reinforced epoxy polymer were proven by using the alkali treatment.

The ultimate tensile strength took place at 0.25 M NaOH solution with 1-hour soaking time, i.e. 49.875 MPa, an improvement of 16.4% from untreated composite. The tensile modulus at this condition gave the improvement of 13.6% from untreated fiber composite. The ultimate flexural strength also occurred at 0.25 M NaOH solution with 1 hour of soaking time, i.e 96.71 MPa, an improvement of 24.42% from untreated fiber composite. However, the ultimate flexural modulus happened at 0.5 M NaOH solution with 4 hours soaking time, i.e. 6948 MPa; on improvement of 148% from untreated composite. The ultimate impact strength of treated *Arenga pinnata* fiber reinforced epoxy composite took place at 0.5 M NaOH solution with 8 hours soaking time, i.e. 60 J/m with improving of 9.8% from untreated composite. The SEM analysis has been conducted to provide the analysis on interface adhesion between the surfaces of fiber with the matrix.

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

SIFAT MEKANIKAL KEPADA KOMPOSIT EPOKSI BERTELULANG GENTIAN ARENGA PINNATA YANG MENDAPAT RAWATAN ALKALI

Oleh

DANDI BACHTIAR

Mei 2008

Pengerusi : Profesor Ir. Mohd. Sapuan Salit, PhD

Fakulti : Kejuruteraan

Matlamat dalam kajian ini adalah untuk menentukan sifat mekanikal (tegangan, lentur dan impak) bagi gentian *Arenga pinnata* bertetulang komposit epoksi setelah mendapat rawatan alkali kepada gentian *Arenga pinnata*. Gentian mendapat rawatan 0.25 M dan 0.5 M larutan dengan masa perendaman 1 jam, 4 jam dan 8 jam. Gentian dicampurkan dengan komposit epoksi pada 10% daripada jumlah kandungan gentian *Arenga pinnata*. Eksperimen untuk membuat spesimen dikendalikan secara manual.

Tegangan yang terjadi pada gentian *Arenga pinnata* tanpa rawatan adalah 466.07 MPa manakala tegangan modulusnya 3.9 GPa. Sedangkan tegangan pada epoksi sahaja adalah 69.39 MPa manakala tegangan modulus 2.3 GPa.

Keputusan daripada ujian yang menunjukkan kenaikan sifat-sifat mekanikal daripada gentian *Arenga pinnata* bertetulang komposit epoksi telah dibuktikan dengan

pemakaian rawatan alkali. Tegangan tertinggi terjadi pada rawatan 0.25 M alkali dengan waktu perendaman selama 1 jam, yaitu 49.875 MPa, dengan kenaikan sejumlah 16.4% dibandingkan dengan komposit tanpa rawatan gentian. Tegangan modulus memberikan kenaikan 13.6% dibandingkan dengan komposit tanpa rawatan. Lenturan tertinggi juga terjadi pada 0.25 M dan 1 jam perendaman, yaitu 96.71 MPa, dengan kenaikan 24.42% dibandingkan dengan komposit tanpa rawatan. Akan tetapi, lenturan modulus terjadi pada 0.5 M rawatan alkali dan 4 jam masa perendaman, yaitu 6948 MPa, dengan kenaikan sebesar 148% daripada komposit tanpa rawatan. Kekuatan impak tertinggi terjadi pada 0.5 M rawatan alkali dan 8 jam masa perendaman, yaitu 60 J/m dengan kenaikan 9.8% daripada komposit tanpa rawatan. Alat pengimbas mikro elektron telah digunakan untuk pemerhatian di antara permukaan gentian dan susunan matrik.

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Last but not least, thanks to mother, brothers, sisters and my wife and children for their continous inspiration and encouragement to complete my project thesis.

I convey my thanks to all of my colleagues, friends, housemate and UPM support staff.

I certify that an Examination Committee has met on 30 October 2007 to conduct the final examination of Dandi Bachtiar on his Master of Science thesis entitled "Mechanical Properties Of Alkali-Treated Sugar Palm (*Arenga Pinnata*) Fiber Reinforced Epoxy Composites" In accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree.

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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:

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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.

DANDI BACHTIAR

Date: 16 March 2008

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LIST OF ABBREVIATIONS

ABBREVIATIONS

ASTM	American Society for Testing and Materials
CO_2	Carbon Dioxide
ESEM	Environmental Scanning Electron Microscope
FTIR	Fourier Transfer Infra Red
NaOH	Natrium Hydroxide or Sodium Hydroxide
RTM	Resin Transfer Molding
SEM	Scanning Electron Microscope
UB	Unit Break
UD	Uni Directional
XPS	X-ray Photoelectron Spectroscopy

NOMENCLATURE

A	Cross sectional area of test specimen (mm^2)
A	Concentration of solution (M)
D	Distance between grip (mm)
E	Tensile modulus of test specimen (Pa)
F	Pulling force applied on test specimen (N)
S_τ	Tensile stress of specimen (Pa)
L	Support span (mm)

P	Load at yield (N)
V	Volume of concentration (litre)
b	Width (mm)
d	Thickness (mm)
ε	Strain of test specimen
σ	Stress applied on test specimen (Pa)
σ_{max}	Flexural strength (Pa)

CHAPTER 1

INTRODUCTION

1.1 Background

Recently, growing environmental awareness has resulted in a renewed interest in the use of natural material for many applications. This paradigm has forced industries like automotive, packaging and construction to search for new materials to make the conventional composite materials be a environmentally friendly material. The composite materials mostly nowadays employed well-established fibers such as glass, carbon and aramid as the reinforcement. These inorganic fibers present disadvantages like their non-biodegradability, expensive, abrasive and non-renewable.

Compared to inorganic reinforcing fibers, natural fibers have a number of benefits, including low density and bio-degradability, less abrasiveness, lower cost and renewable. Natural fiber composites are likely to be environmentally superior to glass fiber composites in most cases (Joshi *et al*., 2004). Several natural fibers like jute, pine, sisal, flax, hemp, kenaf, coir, and abaca have been used by researchers to replace the inorganic fibers (glass, aramid and carbon) in reinforced composites (Wambua *et al*, 2003). So far, a good number of automotive components previously made by glass fiber composites are now being manufactured using natural fiber reinforced composites (Sapuan, 2007).

Unfortunately, several disadvantages of natural fibers such as thermal and mechanical degradation during processing can make them undesirable for certain applications. Natural fiber reinforced composites also have several drawbacks such as poor wettability, incompatibility with some polymeric matrices and high moisture absorption by the fibers. The main problem often encountered in its use is the fiber-matrix adhesion problem that is incompatibility between the hydrophilic natural fibers and the hydrophobic polymer matrix. This problem may be improved by fiber-surface chemically treatment. Alkali treatment is a common method to clean and modify the fiber surface to lower surface tension and enhance interfacial adhesion between a natural fiber and a polymeric matrix (Bledzki *et al*., 1999). Several publications have discussed the effects of alkali treatment on structure and properties of natural fibers such as kenaf, hemp (Aziz and Ansell, 2004), flax (Weyenberg *et al*., 2006), jute (Ray *et al*., 2002), and sisal (Rong *et al*., 2001).

In this research, natural fiber that is *ijuk* fiber (*Arenga pinnata* or *Arenga saccharifera*) is used as a suitable candidate to reinforce polymer matrix in composite. *Ijuk* fiber is a kind of natural fiber that comes from *Arenga pinnata* plant, a forest plant that can be found enormously in Southeast Asia like Indonesia and Malaysia. This fiber seems to have properties like other natural fibers, but the detail properties are not generally known yet. Generally, *ijuk* has desirable properties like strength and stiffness and its traditional applications include paint brush, septic tank base filter, clear water filter, door mat, carpet, rope, chair/sofa cushion, and for fish nest to hatch its eggs (Suwartapraja, 2003). In this study an attempt is made to highlight the potential use of this natural fiber in reinforcing polymer composites.

Previous study (Siregar, 2005) on the tensile and flexural properties of *ijuk* epoxy composites is concerned with the woven roving, long random and chopped random *ijuk* epoxy composites and it is found that the woven roving *ijuk* epoxy composites gave better properties compared to long random and chopped random fiber composites. However, all the samples showed inferior properties compared with the glass fiber epoxy composites (Deng *et al.*, 1999). Hence, the treatment of fiber is needed to improve the materials.

1.2 Problem Statement

The *Arenga pinnata* fiber composites still show inferior properties compared with the glass fiber epoxy composites. Therefore, extended work is needed to improve the performance of composites. One of the improvement steps is the treatment of *Arenga pinnata* fiber. In this work, the alkali treatment is used for the improvement of the properties of composites.

1.3 Objectives of the Study

The objectives of this study are as follows:

1. To investigate the mechanical properties and chemical content of *Arenga pinnata* fiber.
2. To investigate the influence of alkali treatment on the morphological characteristics of *ijuk* fiber.
3. To investigate the influence of alkali treatment on tensile, flexural and impact properties of *ijuk* fiber reinforced epoxy composites.

1.4 Scope of the Study

Improvement of the mechanical properties of *ijuk* fiber reinforced epoxy composites is investigated. Research is conducted for the fiber treatment i.e. alkalization and examination of the effect of fiber treatment on the mechanical properties i.e. tensile, flexural and impact strength of the composites and the results are compared with those untreated fiber composites.

1.5 Structure of the Thesis

Chapter 1 gives the background of studies, and also presents the objectives of the study. A literature survey of research work in various areas relevant to this research is presented in Chapter 2. The survey started with a comprehensive literature survey on the manufacturing and properties of composite products made out of natural fiber and plastic. A review of the physical and mechanical properties of *Arenga pinnata* fiber is also included in this chapter.

The methodology of the study is described in Chapter 3. This chapter presents techniques to determine the chemical content of *Arenga pinnata* fiber, technique to determine the mechanical (tensile strength) properties of *Arenga pinnata* fiber, techniques of the preparation of composites and the determination of mechanical properties of composites. This chapter also presents the techniques of the alkali treatment and the techniques of the morphological properties of the broken composites.

Chapter 4 described the results and discussion of the study. This chapter discussed the mechanical properties of the composites such as tensile, flexural, and impact tests. The results from Scanning Electron Microscopy (SEM) were also included in this chapter. Finally, the conclusions and recommendations for further works are presented in Chapter 5.