PROPERTIES OF KENAF (*HIBISCUS CANNABINUS L.*) BAST FIBRE REINFORCED UNSATURATED POLYESTER COMPOSITE

By

AW YEONG CHEE HONG

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

July 2004

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

PROPERTIES OF KENAF (*HIBISCUS CANNABINUS L.*) BAST FIBRE REINFORCED UNSATURATED POLYESTER COMPOSITE

By

AW YEONG CHEE HONG

July 2004

Chairman: Jalaluddin Harun, Ph.D.

Institute: Institute of Advanced Technology

The main purpose of this research is to exploit new bio-fibre resources for the structural composite industries. Kenaf bast fibre was combined with thermosetting resin matrix to produce advance composites and its mechanical and dimensional stability properties were investigated. Unsaturated polyester was used as matrix resin in this project which consist 44-48% of styrene monomer and form gel in 24-30 minutes with 1% methyl ethyl ketone peroxide.

Biological retting and chemical retting were introduced to prepare the fibre. In biological retting, the bast layer of kenaf was submerged into a water-bath filled with sandy soil (pH = 8.9) and water for 3 days under constant temperature of 30 ± 2 ºC. For chemical retting, the bast layer is submerged in 5% sodium hydroxide (NaOH) and boiled under high temperature (80 ºC) for 75 minutes. Modified water retting reduced the retting time to 3 days compared to normal water retting process which required 5 to

30 days. However, chemical retting produced weaker fibres due to the extreme processing condition.

The kenaf bast fibre was well incorporated in the unsaturated polyester resin matrix and successfully hot-pressed into panels. The composites were fabricated using unidirectional and cross-ply lamination with different fibre volume fraction (40%, 50% and 60%). Chemical analysis, mechanical tests, Izod pendulum impact test and analytical test were carried out. Specimens were further observed under Phillips XL30 scanning electron microscope (SEM).

Generally, the main effects of fibre content, lay-up method and fibre type significantly influenced the properties of kenaf bast fibre reinforced unsaturated polyester composites, except the fibre type has no significance influence on the impact resistance, water absorption and thickness swelling of kenaf composites. However, interactions of the main effects were dominated in each mechanical and dimensional stability properties such as the influence of interaction between fibre content - lay-up and fibre type - lay-up method.

Overall, biological retted fibre composites showed better physical and mechanical properties compare to chemical retted fibre composites at the same fibre content and lay-up method. The tensile strength and flexural strength of 60% fibre content composites with biological retted fibre was 232 MPa and 248 MPa, respectively.

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

CIRI-CIRI KOMPOSIT GABUNGAN GENTIAN KULIT KENAF (*HIBISCUS CANNABINUS L.*) DAN POLIESTER TAK TEPU

Oleh

AW YEONG CHEE HONG

Julai 2004

Pengerusi: Jalaluddin Harun, Ph.D.

Institut: Institut Teknologi Maju

Tujuan penyelidikan ini adalah untuk mengeksploitasi gentian tumbuhan bagi penggunaan dalam industri kayu gubah. Gentian tumbuhan dicampurkan dengan plastik termoset untuk menghasilkan komposit yang lebih tahan. Ciri-ciri mekanikal dan analisis telah diselidik. Plastik termoset yang digunakan ialah poliester tak tepu yang mengandungi 44%-48% monomer stirena dan membentuk gel dalam 24-30 minit jika bercampur dengan 1% metil etil keton peroksida.

Dua kaedah telah digunakan untuk menghasilkan gentian, termasuk mengasingkan gentian kulit kenaf secara biologikal dan secara kimia. Dalam kaedah biologi, gentian kulit kenaf diasingkan dengan merendamnya dalam air yang mengandungi tanah pasir (pH = 8.9) selama 3 hari pada suhu 30 ± 2 ºC. Kaedah kimia pula adalah merendamkan kulit kenaf ke dalam cecair yang mengandungi 5% natrium hidroksida dan dimasakkan pada suhu 80 ºC selama 75 minit. Kaedah biologi telah berjaya mengurangkan masa pemprosesan ke 3 hari berbanding dengan kaedah konvensional yang memerlukan 5-30

hari. Tetapi, kaedah kimia menghasilkan gentian yang kurang kuat akibat keadaan pemprosesan yang ekstrem.

Dalam penyelidikan ini, gentian kulit kenaf berjaya digabungkan dengan baik dalam poliester tak tepu dan berjaya ditekan-panaskan menjadi keping. Komposit ini diperbuat dengan lapisan secara ekaarah dan berpalang dengan kandungan gentian yang berbeza (40%, 50% dan 60%). Analisis kimia, ujian mekanikal, ujian hentaman Izod dan analisis telah dijalankan. Sampel komposit selanjutnya diperiksakan di bawah mikroskop pengimbasan electron (SEM).

Secara amnya, kandungan gentian, cara melapis and jenis gentian mempunyai kesan bererti ke atas ciri-ciri komposit gabungan gentian kulit kenaf dan poliester tak tepu, kecuali jenis gentian tidak memberi kesan kepada ketahanan hentaman, penyerapan air and pengembangan fizikal. Tetapi, interaksi antara factor-faktor utama memberi kesan bererti kepada ciri-ciri mekanikal and fizikal, seperti interaksi antara jenis genting dengan cara melapis dan interaksi antara kandungan gentian dengan cara melapis. air.

Pada keseluruhannya, komposit gentian yang diperbuat dengan menggunakan gentian biologi menunjukkan ciri-ciri analisis dan mekanikal yang lebih baik berbanding dengan komposit diperbuat dengan menggunakan gentian kimia, pada kandungan gentian dan cara melapis yang sama. Daya tegangan dan daya lenturan untuk komposit bergandungan 60% gentian yang diperbuat daripada gentian biologi masing-masing adalah 232 MPa dan 248 MPa.

ACKNOWLEDGEMENT

At first, I would like to thank to my Supervisor Committee, Dr. Jalaluddin Harun (Chairman), Dr. Khairul Zaman Hj. Mohd. Dahlan, and Dr. Azmi Yahya for their invaluable guidance and advice throughout the this study.

My sincere thanks to Mr. C.K. Ng of Revertex (M) Sdn. Bhd., for his kind in supplied the unsaturated polyester resin with no charge. My appreciation also goes to Malaysia Institute for Nuclear Technology Research (MINT) and Inforport UPM for their assistance and cooperation in providing necessary equipments. In addition, I would like to thank Dr. C.C. Wong of Malaysia Agriculture Research and Development Institute (MARDI), who supplied kenaf plant for this study.

Finally, I would like to thank all who rendered support in one way or another during my study. Sincere thank are dedicated to my dearest parents, sister, brother and my wife - Ainee, for their spiritual support and care. This project could not have completed smoothly without their support.

Thank you.

I certify that an Examination Committee met on 2nd July 2004 to conduct the final examination of Aw Yeong Chee Hong on his Master of Science thesis entitled "Properties of Kenaf (*Hibiscus cannabinus L.*) Bast Fibre Reinforced Unsaturated Polyester Composite" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Faizah Abood Harris,Ph.D.
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Mansor Ahmad, Ph.D.
Associate Professor
Faculty of Science & Environment Studies
Universiti Putra Malaysia
(Member)

Paridah Md. Tahir, Ph.D.
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Member)

Mohd Nor Yusof, Ph.D.
Director Wood Chemistry
Research Division
Forest Research Institute Malaysia (FRIM)
(Independent Examinar)

_____
GULAM RUSUL RAHMAT ALI, Ph.D.
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date :

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

Jalaluddin Bin Harun, Ph.D.
Institute of Advance Technology
Universiti Putra Malaysia
(Chairman)

Khairul Zaman Hj. Mohd. Dahlan, Ph.D.
Director, Radiation Division
Malaysia Institute for Nuclear Technology Research (MINT)
(Member)

Azmi Bin Yahya, Ph.D.
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

_____
AINI IDERIS, Ph.D.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date :

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

_____

AW YEONG CHEE HONG

Date:

TABLE OF CONTENT

Page

ABSTRACT i
ABSTRAK iii
ACKNOWLEDGEMENT v
APPROVAL vi
DECLARATION viii
LIST OF TABLES xii
LIST OF FIGURES xiii
LIST OF ABBREVATIONS xvi

CHAPTER

1 INTRODUCTION

1.1 Background 1
1.2 Statement of Problem 3
1.3 Objective 4

2 LITERATURE REVIEW

2.1 Natural Fibres 5
2.1.1 Composition and Morphological of Natural Fibre 7
2.1.2 Advantages and disadvantages of natural fibres 9
2.1.3 Mechanical properties of natural fibres 10
2.1.4 Kenaf 11
2.1.5 Retting 13
2.1.6 Lay-up sequence of Long fibres 16
2.2 Matrices 17
2.2.1 Polymer matrices 17
2.2.2 Thermosets 19
2.2.3 Unsaturated polyester resin (UPR) 20
2.3 Polymeric composite 22
2.3.1 Natural fibre-reinforced polymeric composite 24
2.3.2 Common Thermosetting Composites Processing Techniques 26
2.3.3 Effects of Moisture on Natural Fibre-Reinforced Composites 31
2.3.4 Strength of Composites and the Basic of Load Transfer 32

3 MATERIALS AND METHODS

3.1 General 37
3.2 Material and Composites 37
3.2.1 Raw Materials 37
3.2.2 Cleaning and Decortications 38
3.2.3 Retting 39
3.2.4 Beating and Carding (fibre separation) 40
3.2.5 Fabrication of Composites 41
3.2.6 Determination of Composite Fibre Volume Fraction 43
3.3 Raw Materials and Composite Assessment 44
3.3.1 Fibre Bundles Tensile Test 44
3.3.2 Composite Assessment 46
3.3.3 Conditioning 51
3.4 Chemical Analysis of Kenaf Core and Bast Fibre 52
3.5 Surface Analysis - Scanning Electron Microscope (SEM) 52
3.6 Statistical Analysis 52
3.6.1 Experimental Parameters 52

4 RESULTS AND DISCUSSION

4.1 Properties and Processing of Raw Materials 54
4.1.1 Chemical Composition of Kenaf Bast Fibre 56
4.1.2 Tenacity of Kenaf Bast Fibre 58
4.2 Appearance of Composite 60
4.3 Mechanical Properties of Kenaf Bast Fibre Reinforced Unsaturated Polyester (KBF-UP) Composites 61
4.3.1 Effects of fibre type and lay-up method on the tensile strength of KBF-UP composites 61
4.3.2 Effects of fibre type and lay-up method on the tensile modulus of KBF-UP composites 64
4.3.3 Effects of the interaction of fibre type, lay-up method and fibre content on the flexural strength of KBF-UP composites 66
4.3.4 Effects of fibre type, lay-up method and fibre content on the flexural modulus of KBF-UP composites 70
4.3.5 Effects of fibre content and lay-up method on the impact resistance of KBF-UP composites 73
4.3.6 Effects of fibre type and lay-up method on the dimensional stability of KBF-UP composites 75
4.3.7 Effects of fibre type and lay-up method on the specific gravity of KBF-UP composites 80

4.4 Comparisons between Cross-Ply and Unidirectional Laminated KBF-UP Composites (Effect of Lay-up Sequence) 83
4.5 Comparisons of Mechanical Properties between Biological and Bhemical Retted Fibre Composites (Effect of Fibre Type) 89
4.5.1 The Effect of Retting Method 90
4.6 SEM Analysis of Kenaf bast fibre and Kenaf Bast Fibre Reinforced Unsaturated Polyester (KBF-UP) Composites 94
4.7 Future Prospect of Natural Fibre Composites and Recommended Applications 97

5 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion 100
5.2 Recommendation 101

REFERENCES 103
APPENDICES 109
BIODATA OF THE AUTHOR 116