UNIVERSITI PUTRA MALAYSIA

PHYSIO-CHEMICAL AND MECHANICAL PROPERTIES OF DIFFERENT MORPHOLOGICAL PARTS OF SUGAR PALM FIBRE REINFORCED POLYESTER COMPOSITES

SAHARI BIN JAPAR

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By

SAHARI BIN JAPAR

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

April 2011

DEDICATIONS

For all your advice and encouragement, this thesis is gratefully dedicated to my beloved parent, family and my friends. Thank you very much for your continuous support and effort towards the publication of this thesis.

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

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Chairman : Professor Mohd Sapuan Salit, PhD, P. Eng

Institute : Institute of Advanced Technology

Recently, due to increase environmental concerns, scientists and technologists have placed much importance on the application of natural fibre composites especially in biocomposites. The purpose of this research is to study the properties of single fibre from different morphological parts of sugar palm tree and properties of sugar palm fibre from different parts reinforced unsaturated polyester composites. These studies have been done in order to evaluate the potentiality of fibre from different morphological parts of sugar palm tree i.e sugar palm frond (SPF), sugar palm bunch (SPB), sugar palm trunk (SPT) and black sugar palm fibre (*ijuk*) as which is can be used as eventual raw materials for the reinforcement of polymer matrix composites which are suitable in various applications such as building, automotive, furniture and packaging.

The tensile, chemical and physical properties of single fibres from all parts were evaluated. The results showed that the highest tensile strength and tensile modulus were obtained from the SPF followed by SPB, *ijuk* and SPT. These results have been proven with the results of their chemical compositions where the highest cellulose content was obtained from SPF (66.49%) and followed by SPB (61.76%), *ijuk*

(52.29%), and SPT (40.56%).

The mechanical and physical properties of natural fibres from different parts of sugar palm tree reinforced unsaturated polyester composites which are SPF/PE, SPB/PE, SPT/PE and *ijuk*/PE have also been evaluated in this study. For tensile strength analysis, it is found that SPF/PE shared the higher value of 15.179 MPa (±2.425) followed by SPB/PE, *ijuk*/PE and SPT/PE with 12.809 MPa (±1.580), 11.473 MPa (±0.536) and 9.817 MPa (±1.890) respectively. The higher value of flexural strength and flexural modulus obtained from SPT/PE with the value of 41.906 MPa and 3.363 GPa respectively. For impact strength analysis, similar trends were found with the tensile stress and tensile strain results and SPF/PE showed the higher value of impact strength (8.091 kJ m^{-2}) followed by SPB/PE, *ijuk*/PE and SPT/PE. In cases of physical properties, it is found that SPF/PE showed the higher value of water absorption and thickness swelling with the value of 1.57%, and 1.56% followed by SPB/PE (1.35%, 1.11%), *ijuk*/PE(0.65%, 0.76%) and SPT/PE (0.39%, 0.50%). Scanning electron microscopy (SEM) test were carried out after the mechanical test to observe the interface bonding of fibre and matrix.

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

SIFAT-SIFAT FISIO-KIMIA DAN MEKANIKAL KOMPOSIT POLIESTER DIPERKUAT GENTIAN DARIPADA BAHAGIAN POKOK ENAU YANG BERBEZA

Oleh

SAHARI BIN JAPAR

April 2011

Pengerusi : Professor Mohd Sapuan Salit, PhD, P. Eng

Institut : Institut Teknologi Maju

Baru-baru ini, disebabkan peningkatan keperihatinan terhadap alam sekitar, saintis dan teknologis menekankan terlalu banyak kepentingan terhadap penggunaan gentian semula jadi khususnya dalam biokomposit. Tujuan penyelidikan ini ialah untuk mengkaji sifat-sifat gentian tunggal daripada bahagian morfologi pokok enau yang berbeza dan sifat-sifat komposit poliester tak tepu diperkuat gentian daripada bahagian pokok enau yang berbeza. Kajian ini dilaksanakan untuk menilai potensi gentian daripada bahagian morfologi pokok enau yang berbeza iaitu pelepah pokok enau (SPF), tandan pokok enau (SPB), batang pokok enau (SPT) dan gentian hitam pokok enau (*ijuk*) sebagai bahan asas untuk memperkuatkan komposit polimer yang sesuai dalam pelbagai aplikasi seperti bangunan, automotif, perabot dan pembungkusan.

Sifat-sifat ketarikan, kimia dan fizikal bagi gentian tunggal daripada bahagian yang berlainan dinilai. Keputusan menunjukkan bahawa kekuatan tarik dan modulus tarik yang paling tinggi diperolehi daripada SPF diikuti oleh SPB, *ijuk* dan SPT. Keputusan ini dibuktikan oleh keputusan komposisi kimia dimana kandungan

selulosa yang paling tinggi diperolehi daripada SPF (66.49%) dan diikuti oleh SPB (61.76%), *ijuk* (52.29%) dan SPT (40.56%).

Sifat-sifat mekanikal dan fizikal komposit polyester tak tepu diperkuat gentian daripada bahagian pokok enau yang berbeza iaitu SPF/PE, SPB/PE, *ijuk*/PE dan SPT/PE juga dinilai dalam penyelidikan ini. Untuk analisis kekuatan tarik, didapati bahawa SPF/PE menunjukkan nilai yang tertinggi iaitu 15.179 (±2.425) diikuti oleh SPB/PE, *ijuk*/PE dan SPT/PE dengan masing-masing bernilai 12.809 MPa (±1.580), 11.473 MPa (±0.536) dan 9.817 MPa (±1.890). Nilai kekuatan lentur dan modulus lentur yang tertinggi diperolehi daripada SPT/PE iaitu 41.906 MPa and 3.363 GPa. Bagi analisis kekuatan tumbuk, urutan yang sama diperolehi daripada keputusan tekanan tarik dan renggangan tarik iaitu SPF/PE menunjukkan nilai yang paling tinggi dengan nilai 8.091 kJ m^{-2} diikuti oleh SPB/PE, *ijuk*/PE dan SPT/PE. Sementara untuk sifat fizikal, didapati bahawa SPF/PE menunjukkan nilai penyerapan air dan pembengkakkan tebal yang paling tinggi iaitu 1.57%, dan 1.56% diikuti oleh SPB/PE (1.35%, 1.11%), *ijuk*/PE(0.65%, 0.76%) dan SPT/PE (0.39%, 0.50%). Ujian imbasan mikroskop elektron (SEM) dilakukan selepas ujian mekanikal untuk melihat antara muka gentian dan matriks.

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I certify that a Thesis Examination Committee has met on **04 April 2011** to conduct the final examination of **Sahari Japar** on his thesis entitled **" Physio-chemical and mechanical properties of different morphological parts of sugar palm fibre reinforced polyester 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:

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

SAHARI BIN JAPAR

Date: 4 April 2011

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LIST OF ABBREVIATIONS

A.D	air dry
ASTM	American Society for Testing and Material
CO_2	Carbon dioxide
FTIR	Fourier transform infrared spectroscopy
INTROP	Tropical Forestry and Forest Products
KBr	Potassium bromide
KFUPC	Kenaf fibre unsaturated polyester composites
MEKP	Methyl ethyl ketone peroxide
NaOH	Sodium hydroxide
OW	Oven dry weight
PE	Unsaturated polyester
PET	Polyethylene terephthalate
PP	Polypropelyne
PVC	Polyvinyl chloride
SEM	Scanning electron microscope
SPB	Sugar palm bunch
SPF	Sugar palm frond
SPT	Sugar palm trunk
TAPPI	Technical Association of the Pulp and Paper Industry.
WA	Water absorbed
WW	Wet weight

NOMENCLATURE

ρ	density of fibre (g/cm^3)
m	mass of fibre (g)
V	volume of water (cm^3)
S_τ	tensile strength of test specimen (MPa)
F	pulling force applied on test specimen (kN)
A	cross section area of test specimen (mm^2)
E	tensile modulus of test specimen (MPa)
σ	stress applied on test specimen (MPa)
ε	strain of test specimen (mm/mm)
σ_{max}	flexural strength (MPa)
E_H	flexural modulus (MPa)
R	rate of crosshead motion, mm/mm
L	support span, mm
Z	rate of straining of the outer fibre, mm/mm/min; Z shall equal 0.01
P	load at yield (maximum load)
L	support span (mm)
b	width (mm)
d	thickness (mm)

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