UNIVERSITI PUTRA MALAYSIA

MECHANICAL PROPERTIES OF SUGAR PALM FIBRE-REINFORCED EPOXY COMPOSITES

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By

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

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

MECHANICAL PROPERTIES OF SUGAR PALM FIBRE-REINFORCED EPOXY COMPOSITES

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December 2009

Chairman : Mohd Sapuan bin Salit, PhD, PEng

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The potential use of natural fibres as substitutes to synthetic fibres (glass in particular) is of great interest due to growing global environmental and social concern, uncertainties in the supply and price of petroleum based products, and new environmental regulations that have forced the search for renewable green materials, which are compatible with the environment. In addition, glass fibres can also cause acute irritation to the skin, eyes and upper respiratory tract if one is being exposed to their use for a prolonged period of time. The goal of this study was to explore the possibility of using the sugar palm *(Arenga pinnata)* fibres as the reinforcement material in epoxy matrix.

The mechanical performances of composite materials strongly depend on the nature and orientation of the fibre, the nature of the matrix and the quality of adhesion between the two constituents. One of the biggest challenges for natural fibres is the ability for moisture repellence. Therefore, tests were conducted to study the moisture absorption

behaviour of the epoxy resin and also the composites. Test results showed that sugar palm fibre epoxy composite absorbed about 0.93% moisture after being immersed in water for 33 days.

Another challenge was to understand the degree of adhesion between the fibre and matrix. The surface properties of the sugar palm fibre were modified using ‘biological’ treatments. In this study sea water, fresh (pond) water and sewage water were used as treatment agents. This led to biological, chemical and water degradation to the sugar palm fibre. Interfacial shear strengths were studied using the single fibre pull out test and the results showed that the fibres treated with sea water exhibited the strongest fibre-matrix bonding. Morphological and structural changes of the fibres were investigated using scanning electron microscope (SEM). It was found that the biological treatments had modified the surface properties of the sugar palm fibre thus resulted in a better adhesion quality as compared to the untreated fibre.

A series of mechanical tests namely tensile, flexural and impact were conducted on the composites with 10%, 15%, 20% and 30% (by volume) of randomly short chopped fibres. The results showed that the strengths increased with increased fibre loadings of up to 20% but the composite with 30% fibre content showed the opposite behaviour.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SIFAT MEKANIKAL KOMPOSIT EPOKSI YANG DIPERKUAT DENGAN GENTIAN POKOK GULA KABUNG

Oleh

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Potensi penggunaan gentian semula jadi sebagai pengganti kepada gentian sintetik (terutamanya gentian kaca) mendapat banyak perhatian disebabkan meningkatnya keperihatinan terhadap masalah alam sekitar dan sosial, ketidakpastian bekalan dan harga produk berasaskan petroleum, dan peraturan baharu alam sekitar yang telah memaksa kepada pencarian bahan hijau, yang lebih serasi dengan persekitaran. Tambahan pula, gentian kaca juga boleh menyebabkan gangguan akut kepada kulit, mata dan saluran atasan pernafasan jika seseorang itu terdedah kepada penggunaannya dalam masa yang agak lama. Tujuan kajian ini adalah untuk meneroka kemungkinan menggunakan gentian pokok gula kabung *(Arenga pinnata)* sebagai bahan penguat di dalam matriks epoksi.

Sifat mekanikal bahan komposit bergantung kuat kepada keadaan semula jadi dan orientasi gentian, keadaan semula jadi matriks yang digunakan dan kualiti lekatan di antara kedua-duanya. Salah satu daripada cabaran terbesar gentian semula jadi ialah kebolehannya untuk menghalang kelembapan. Oleh itu, ujian telah dijalankan untuk

mengkaji sifat serapan kelembapan bagi epoksi dan juga kompositnya. Keputusan ujian menunjukkan komposit epoksi diperkuat dengan gentian gula kabung menyerap 0.93% kelembapan setelah direndam di dalam air selama 33 hari.

Satu lagi cabaran ialah memahami tahap pelekatan di antara gentian dan matriks. Sifat permukaan gentian gula kabung diubahsuai menggunakan kaedah ‘biologi’. Dalam kajian ini, air laut, air tasik dan air kolam takungan telah digunakan sebagai agen pengubahsuaian. Kekuatan ricih antara muka telah dikaji melalui ujian tarikan keluar satu gentian dan keputusan menunjukkan gentian yang diubahsuai menggunakan air laut mempunyai kekuatan gentian-matriks paling tinggi. Gentian gula kabung telah mengalami penurunan secara biologi, kimia dan air melalui kaedah tersebut. Perubahan struktur dan morfologi telah disiasat menggunakan mikroskop imbasan elektron (SEM).

Satu siri ujian mekanikal iaitu terikan, lenturan dan hentaman telah dijalankan ke atas komposit dengan kandungan rawak gentian pendek 10%, 15%, 20% dan 30% (mengikut isi padu). Keputusan menunjukkan kekuatan komposit telah meningkat dengan pertambahan gentian sehingga 20% tetapi komposit dengan kandungan 30% gentian menunjukkan pengurangan kekuatan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as partial fulfilment of the requirement for the degree of Doctor of Philosophy. 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.

ZULKIFLLE BIN LEMAN

Date: 31st December 2009

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	American Standard of Testing Materials
BOD	Biochemical Oxygen Demand
CNC	Computer Numerical Control
DHBA	Dihydroxybenzoic Acid
DO	Dissolved Oxygen
DPL	Date Palm Leave
ENR	Epoxidised Natural Rubber
ESEM	Environmental Scanning Electron Microscope
FTIR	Fourier Transform Infrared Spectroscopy
GN	Giga Newton
IFSS	Interfacial Shear Strength
kGy	KiloGray
kPa	Kilo Pascal
LDPE	Low Density Polyethylene
MA	Malaeic Anhydride
MMA	Methyl Methacrylate
MPa	Mega Pascal
N	Newton
NaOH	Sodium Hydroxide
PMPPIC	Poly (methylene)-(polyphenylisocyanate)
PP	Polypropylene
ppm	Parts per million
PS	Polystyrene
PU	Polyurethane
PVC	Polyvinylchloride
RFL	Resorcinol-formaldehyde Latex

rpm	Revolution per minute
SD	Standard Deviation
SEM	Scanning Electron Microscope
SUPFREC	Sugar Palm Fibre Reinforced Epoxy Composite
T_g	Glass Transition Temperature

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Natural fibre reinforced composites is an emerging area in polymer science. The natural fibre (agrofibres) reinforced composites, sometimes referred to as biocomposites or eco-composites, are subject of many ongoing scientific and research projects. The potential use of natural fibres as substitutes to synthetic fibres (glass in particular) is of great interest due to growing global environmental and social concern, uncertainties in the supply and price of petroleum-based products, and new environmental regulations that have forced the search for renewable green materials, which are compatible with the environment.

As a tropical country, Malaysia has abundant resources of natural fibres that can be obtained from plants and trees. One of them that has not been commercially used as reinforcement is the sugar palm *(Arenga pinnata)* fibre. Traditionally, the local people use the fibres to make brooms, brushes, and ropes especially for cordage on *sampans*. Although the fibres are well known among the locals to have high strength and good resistance to sea water but very little scientific research has been done to study the full potential of these fibres.

Natural fibres are now considered as promising alternatives to synthetic fibres for use in composite materials as reinforcing agents. Synthetic fibres come from nonrenewable resources that can give problems with respect to ultimate disposal at the end of their lifetime since they cannot be thermally recycled by incineration. Synthetic fibres such as glass are also very abrasive, which leads to increased wear of processing equipment such as extruders and moulds. Glass fibres can also cause problems with respect to health and safety, for example, they give skin irritations during handling of fibre products, and processing and cutting of fibre reinforced parts (Stamboulis et al., 2000).

The advantages of natural fibres are their low cost, low density, high strength-to-weight ratio, low energy content, recyclability and biodegradability.

However, one of the significant drawbacks in natural fibres reinforced composites is the poor compatibility of the fibres with the matrix due to the hydrophilic characteristic of the cellulose and the hydrophobic matrix material. Chemical and physical modifications of natural fibres are usually performed to correct for the deficiencies of these materials, especially to improve the wettability which in turns improve the bonding and adhesional properties. Surface modification of natural fibres can be used to optimise properties of the interface, changing the hydrophobic and hydrophilic properties.

1.2 Problem Statements

The most common and widely used fibres in the composite industry are glass fibres. This is because glass fibres have desirable properties of being corrosion resistant, have low stiffness and large elongation, have moderate strength and weight, and in many cases possess efficient manufacturing potential compared to other fibres. Thus, glass fibre composites are used extensively in chemical industries and marine application such as for boat manufacturing or its components.

Although glass fibre composite has great advantages it also has some drawbacks. Besides being costly, prolonged exposure to the glass fibres can cause harmful side effects such as acute irritation to the skin, eyes, and upper respiratory tract. Concerns for long-term development of lung scarring (i.e., pulmonary fibrosis) and cancer have been raised because fibrous glass and other synthetic vitreous fibres, when disturbed, can release fibres that can become airborne, inhaled, and retained in the respiratory tract. Natural fibres can be seen as safer, cheaper and may be better alternative to glass fibres with respect to these concerns.

Generally, natural fibres used in composite making usually have poor interfacial bonding to the matrix especially in the presence of moisture. According to Chow et al. (2000), high moisture absorption in natural fibre composites can lead to dimensional instability and hence pose difficulty during processing.

This research aims to explore the potentials of the sugar palm fibres which have been traditionally used by the village folks for so many years in many applications. One particular application that intrigues the author is the fact that when these fibres are used as ropes, either to leash the cattle or buffalos, the ropes would become stronger and stronger by the day. In use, these ropes are constantly dipped in mud and also bodies of water in the paddy field. Another application of the fibres is their use as cordage on fishing boats or *sampans*. Again, these cords become stronger after being submerged in sea water for a prolonged period of time. One can obviously conclude here that the strength of these fibres increases if they are submerged in mud or sea water. Unfortunately, until today no one can verify whether or not this claim is true.

1.3 Objectives of the Study

This study aims to experimentally determine the mechanical behaviour of the sugar palm fibre reinforced epoxy composites (SUPFREC) in which the fibres have been subjected to different treatment conditions.

The specific objectives of this research are as follows:

1. To determine the interfacial shear strength of the SUPFREC.
2. To determine the moisture absorption behaviour of the SUPFREC.
3. To study the effect of the fibre surface treatments on the surface morphology of the fibres.
4. To relate the fibre surface morphology to the mechanical properties of the SUPFREC.

1.4 Scope of the Study

The mechanical properties investigated in this study were interfacial shear strength, tensile, flexural and impact strengths. In addition, the water absorption behaviour of the composite was also investigated. The fibres were categorised into four different treatment conditions: untreated, submerged in sea water, pond water and sewage (treatment plant) water. The fibre contents were 10%, 15%, 20% and 30% by volume. The matrix used was epoxy and hardener with a mixing ratio of 4:1.

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