UNIVERSITI PUTRA MALAYSIA

MECHANICAL STRENGTH AND THERMAL STABILITY OF WOVEN GLASS/KENAF FIBRE HYBRID-REINFORCED NANOCLAY WITH EPOXY COMPOSITES

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FK 2019 39

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By

TAY CHAI HUA

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

August 2018

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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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August 2018

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This research investigates the hybrid effects between kenaf and glass fibres reinforced in modified epoxy filled with nanoclay. Kenaf fibres were treated with 2M Sodium Hydroxide (NaOH) solution. Epoxy was modified with 1 wt% silicon powder. Nanoclay loading was sonicated at 1.0 wt%, 3.0 wt% and 5.0 wt% with respect to epoxy. Three layers of glass fibres and two layers of kenaf fibres were lay-up alternately, which constitute to 20 wt% of composite. Composites were then fabricated using hot compression moulding technique. Analysis from Fourier Transform Infrared Spectroscopy (FTIR) revealed the absence of hemicellulose, lignin and hydroxyl functional group on TK/Ep composite. Flexural test revealed improved flexural strength and flexural modulus among treated kenaf composites. Impact test was conducted at two different energy levels of 15 J and 30 J. It was observed that composite dispersed with nanoclay is capable of sustaining both the loads. Morphology study through Field Emission Scanning Electron Microscope (FESEM) revealed the roughness on the surface of the fractured treated kenaf fibre. Thermogravimetric Analysis (TGA) result shows that the highest initial decomposition temperature was achieved by GUK/Ep-Si/1% nanocomposite, with 2.386% higher than GTK/Ep-Si/1% nanocomposite. Dynamic Mechanical Analysis (DMA) result reveals that the glass transition temperature (T_g) of 3G2UK/Ep-Si/1% nanocomposite is 6% higher than GTK/Ep-Si/1% nanocomposite which indicates the lower free volume in GUK/Ep-Si/1%. Overall, it can be concluded that composite with treated kenaf has better mechanical properties while composites with untreated kenaf possesses better thermal properties.

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

KEKUATAN MEKANIKAL DAN KESTABILAN HABA GENTIAN ANYAMAN HIBRID KACA/KENAF DIPERKUAT TANAH LIAT NANO KOMPOSIT EPOKSI

Oleh

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Kajian ini dijalankan untuk mengkaji kesan hibrid bagi komposit epoksi terisi tanah liat nano yang diperkukuh dengan gentian kenaf dan kaca. Gentian kenaf dirawat dengan 2M larutan natrium hidroksida (NaoH). Epoksi diubahsuai dengan 1 wt% serbuk silicon. Beban tanah liat nano dipelbagaikan kepada 1.0 wt%, 3.0 wt% dan 5.0 wt% berdasarkan kuantiti epoksi. Tiga lapis gentian kaca dan dua lapis gentian kenaf yang terdiri daripada 20 wt% jumlah komposit disusun secara berselang seli. Komposit kemudiannya dihasilkan menggunakan kaedah pengacuan mampatan panas. Analisa daripada Spektroskopi Inframerah Transformasi Fourier menunjukkan ketiadaan hemiselulosa, lignin dan kumpulan hidroksil pada komposit TK/Ep. Hasil daripada keputusan ujian lenturan menunjukkan peningkatan kekuatan lenturan dan modulus lenturan bagi komposit yang dihasilkan dengan gentian kenaf yang telah dirawat. Ujian impak dijalankan pada tahap tenaga 15 J dan 30 J. Didapati bahawa komposit yang terisi dengan tanah liat nano berupaya untuk menahan kedua-dua tahap tenaga. Kajian morfologi menggunakan Mikroskop Elektron Pengimbas Pancaran Medan (FESEM) mendapati bahawa permukaan gentian kenaf yang patah adalah kasar. Analisa termogravimetri (TGA) menunjukkan bahawa suhu penguraian awal tertinggi adalah daripada nanokomposit GUK/Ep-Si/1% dengan peratusan sejumlah 2.386% lebih tinggi daripada nanokomposit GTK/Ep-Si/1%. Analisis mekanikal dinamik (DMA) menunjukkan yang T_g bagi nanokomposit GUK/Ep-Si/1% adalah 6% lebih tinggi daripada nanokomposit GTK/Ep-Si/1% Ini menunjukkan bahawa nanokomposit GUK/Ep-Si/1% mempunyai jumlah rongga yang lebih banyak. Secara keseluruhannya, komposit dengan gentian kenaf yang dirawat mempunyai ciri ciri kekuatan mekanikal yang lebih baik manakala komposit dengan gentian kenaf yang tidak terawat mempunyari ciri-ciri terma yang lebih baik.

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ACKNOWLEDGEMENTS

This thesis becomes a reality with the kind help and support of many individuals. I would like to extend my sincere thanks to each and every one of them.

First, I want to thank the great algorithm for putting all of this, here and now.

To my parents, Henry Tay and Linda Tay, for their encouragement and financial support in completion of this paper. Beloved siblings, Pauline Tay, Patrick Tay and Pierre Tay for their kind support along the way.

Deepest gratitude to my supervisory committee: Supervisor: Dr Norkhairunnisa Mazlan for her constant guidance and supervision, as well as financial support which allows me to conduct the research with ease. Co-supervisors: Assoc. Prof. Dr. Khalina Abdan and Assoc. Prof. Ir. Dr. Mohamed Thariq bin Haji Hameed Sultan for imparting their knowledge and expertise in completing this endeavour.

To my laboratory colleagues and friends, who have willingly helped out with their abilities; Farid, Reffa, Natasha, A'liya, Qilah, Adam, Ain, Hasfa and Syiro.

Lastly, I humbly extend my gratitude to all concerned people who have co-operated with me in this regard.

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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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LIST OF ABBREVIATIONS

CFRP	Carbon Fibre Reinfoced Plastic
DMA	Dynamic Mechanical Analysis
DMF	Dimethylformamide
E	Elongation at Break
FESEM	Field Emission Scanning Electron Microscope
FRPC	Fibre Reinforced Polymer Composite
FTIR	Fourier Transform Infrared Spectroscopy
HFCL	Composite Reinforced Hybrid Fabric
HSCL	Composite Reinforced Hybrid Strand
IR	Infrared
MA-g-PP	Maleic Anhydride Grafted Polypropylene
MMT	Montmorillonite
MWCNT	Multi Walled Carbon Nanotube
N	Nitrogen
NaOH	Sodium Hydroxide
OHP	Overhead Projector
P	Phosphorus
PDMS	Poly (dimethylsiloxane)
PHCM	Polymer Hybrid Composite Material
TGA	Thermogravimetric Analysis
THF	Tetrahydrofuran
WGFR	Woven Glass Fibre Reel

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CHAPTER 1

INTRODUCTION

1.1 Overview

The ideal image of an airplane as created by aerospace industry exhibit the following criteria; extremely lightweight, possesses wings with variable geometry, run on renewable energy, zero noise pollution and built on reusable and recyclable materials (Tanasa and Zanoaga, 2012). According to Airbus, (2017), one of their commercial jetliners, the A350 XWB uses composite material which made up to more than half of the whole aircraft structure. The advanced composite utilised in A350 XWB is the known Carbon Fibre Reinforced Plastic (CFRP).

Compared to the conventional metal in aircraft, CFRP provides better strength-to-weight ratio. This corresponds to one of the criteria in an ideal airplane, which is extremely lightweight. However, carbon fibres are expensive and glass fibres are advancing to replace carbon fibres in aerospace and even leisure, automotive, construction and sports industries. All of these are due to the low cost of glass and its fairly good mechanical properties. Even though glass fibre is lightweight, it is not reusable or recyclable. Wambua et al., (2003) stated that glass fibres exhibit some other drawbacks that can be fulfilled by natural fibre such as low recyclable. Wambua et al., (2003) also stated that glass fibres exhibit some other drawbacks that can be fulfilled by natural fibre such as low lost cost, low energy consumption, biodegradable, and no health risk when inhaled.

It was reported by Grey (2017) that around 12,000 commercial aircraft will be decommissioned in the next 20 years. This would lead up to retirement of 6000 aircrafts annually. More and more aircraft recycling are expected to be in the future, with increment in flying of commercial aircraft (Grey, 2017; Suomalainen et al., 2014). As of 2013, it was reported by Asmatulu et al., (2013) that a company in Kansas called Carbon Fibre Remanufacturing is able to recycle carbon scrap from CFRP and reuse about 30% of it to make new composite. A significant improvement is achieved in 2017, as it was reported that 80%-85% part of most commercial aircraft can be recycled, depending on its type (Grey, 2017). In comparison to carbon fibre, natural fibres are cheap and recyclable in nature. Implementing natural fibres into aerospace composites would greatly increase rate of aircraft recyclability. At the same time, lighter aircraft can be produced and significantly reduce fuel consumption, cost and emission of CO_2. The progression does not have to be a drastic one, as long as advancement is made with time.

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1.2 Significance of Study

The appealing characteristic of reinforcing natural fibre into composite is its biodegradability and reduction in landfill dependency. With most countries starting to implement taxes on their landfills, it is no wonder that natural fibres are famously researched on for construction, automotive and other industrial uses (Azwa and Yousif, 2013a; Bos et al., 2002). In support to that, clay is one of the most abundant natural filler and widely used in commercial applications (Hossain et al., (2009). Incorporation of clay in composite is not only low cost, but also helps to improve its mechanical and thermal properties (Assaedi et al., 2015). Thus, addition of nanoclay into composite studied here would be beneficial.

1.3 Problem Statement

Natural fibres are susceptible to drawbacks like low modulus, low strength and high moisture absorption as compared to synthetic fibres (Velmurugan and Manikandan, 2007). Reincorporating natural fibre into polymer would produce material with high moisture absorption due to its hydrophilicity. Also, the low compatibility between natural fibre and matrix would weaken the stress transfer ability in composite. This would lead to even lower mechanical properties of composite as mentioned by Fiore et al., (2015).

Researches have been reported on treating natural fibre to improve its compatibility with resin, which includes physical or chemical treatments. This was said to enhance the mechanical properties as well as thermal stability of resulting composite. Besides treatment, incorporation of nanoparticles into composites also leads to performance increment in specific properties. Among the commonly used nanoparticles are graphenes, carbon nanotubes, nanoclays and metal nanoparticles.

In addition to this, hybridizing natural fibres with high strength synthetic fibres will create a balance between environmental impact and performance. A composite with desired stiffness, strength and moisture resistance can be produced and resolve the problems both environmentalist and researchers are dwelling in (Velmurugan and Manikandan, 2007).

Despite their commonness, very few composites are fabricated using both natural fibre treatment, addition of nanoparticles and hybridization of fibres. Lack of work reported on such complex heterogeneity motivates this study to be conducted. This work focuses on effect of natural fibre treatment, hybridization of fibre and dispersion of nanofillers into composites onto its mechanical strength and thermal stability.

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1.4 Objective of Study

The main objective of the study is to analyse the mechanical performance and thermal stability of woven glass/kenaf fibre hybrid-reinforced nanoclay with epoxy composites for aerospace application. Detailed objectives of this study are as follows:

- To observe the hybridization effects between woven glass/kenaf with presence of nanoclay through fractographical analysis
- To investigate the mechanical properties of woven glass/kenaf fibre hybrid-reinforced nanoclay with epoxy composites.
- To analyse the thermal stability of woven glass/kenaf fibre hybrid-reinforced nanoclay with epoxy composites
- To study the dynamic mechanical analysis result of woven glass/kenaf hybrid composite filled with nanoclay

1.5 Scope and Limitation of Study

This research focuses on hybridizing kenaf with glass fibre reinforced in modified epoxy filled with nanoclay. Composites are produced with treated kenaf and with untreated kenaf to compare the effect of alkaline treatment. Parameters for optimum kenaf surface treatment were based on its best tensile strength property through preliminary study. Effect of nanoclay dispersion in epoxy was studied with loadings of 1.0 wt%, 3.0 wt% and 5.0 wt%. Selection of resin and filler sonication period was analysed from thermogravimetric analysis (TGA) result. Stacking sequence of kenaf and glass fibre is limited to Glass-Kenaf-Glass-Kenaf-Glass (GKGKG), thus all mechanical and thermal properties analysed are based on one type of fibre arrangement only. The mechanical properties for all of the composites produced are studied via impact test and flexural test. Selected composites are then further analysed using dynamic mechanical analysis (DMA) and TGA. Morphology and chemical bonding of the samples were investigated using field emission scanning electron microscope (FESEM) and fourier transform infrared (FTIR), respectively which are used to support the mechanical and thermal test result.

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