

UNIVERSITI PUTRA MALAYSIA

MECHANICAL AND THERMAL PROPERTIES OF SURFACE TREATED SUGAR PALM FIBRE-REINFORCED EPOXY BIOCOMPOSITES

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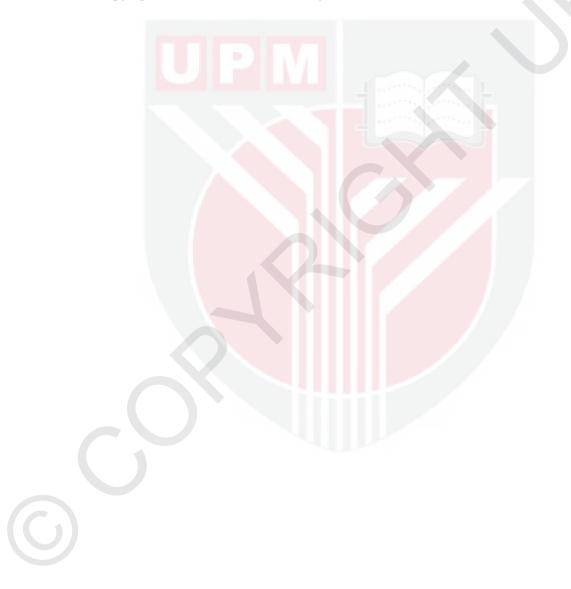
Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

November 2019

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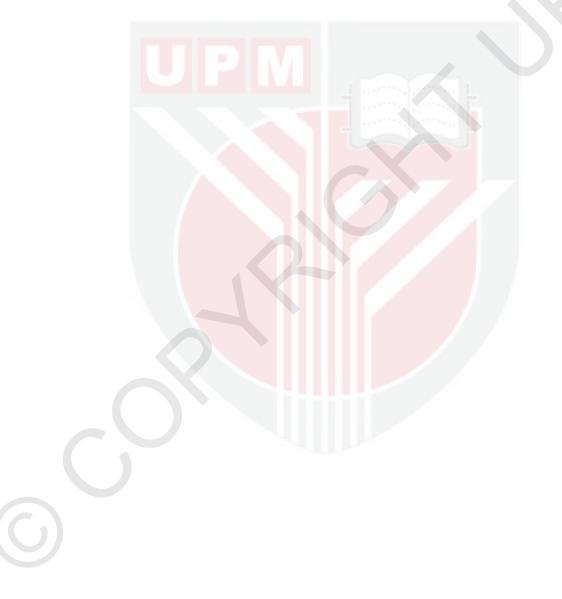
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DEDICATION

This thesis is gratefully dedicated to: My beloved Mother and Father Norzihan Binti Atan Mohamed Latiff Bin Hj. Murad And My Family Thank you for your continuous support and effort towards the completion 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

MECHANICAL AND THERMAL PROPERTIES OF SURFACE TREATED SUGAR PALM FIBRE-REINFORCED EPOXY BIOCOMPOSITES

By

AHMAD SYAHMI BIN MOHAMED LATIFF

November 2019

Chairman Faculty : Associate Professor Mohamad Ridzwan bin Ishak, PhD: Engineering

A number of chemical treatment processes of natural fibres such as jute, kenaf, sisal, flax etc have been practised to improve the structure of natural fibre in order to help them to form a strong bonding with resin in bio-composites making. However, as for sugar palm fibre there are not many treatments available due to limited research has been done on it. The only treatments that can be found for sugar palm fibre are sodium hydroxide (NaOH) and sea water treatments. This thesis focused on the study of new treatment for sugar palm fibre which is benzoylation (benzoyl chloride) treatment. The purpose of benzoylation is to reduce the hydrophilicity of sugar palm fibre and improve its chemical interlocking at the interface. This helps the fibre to be more compatible with polymer matrix and form a strong bonding. The mechanical properties of both untreated and treated sugar palm fibres were studied. The sugar palm fibres were being treated with sodium hydroxide and benzoyl chloride respectively to alter the composition of the fibre and to improve its properties. In single fibre testing, the highest improvement in tensile strength was observed in fibre treated with benzoyl chloride for 30 minutes soaking time with increment of 47.5 % compared to untreated fibre. The second highest was fibre treated with NaOH, showing increment of 35.1 % compared to untreated fibre. For sugar palm composite with 30 % fibre loading, the fibre treated with NaOH showed highest tensile strength with value of 54.8 MPa, followed by fibre treated with benzoyl chloride with 54 MPa and lastly untreated fibre with 38.3 MPa. For thermal properties, benzoylation process show significant improvement in all testing performed which are thermogravimetric analysis (TGA), dynamic mechanical analysis (DMA), thermomechanical analysis (TMA) and differential scanning calorimetry (DSC). This show that benzoylation process gives the fibre and its composites a better thermal stability than other composites. Based on the results obtained, it can be concluded that both benzoyl chloride and sodium hydroxide treatments improved the properties of sugar palm fibres and its composites.



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

SIFAT-SIFAT MEKANIKAL DAN THERMAL SERAT POKOK ENAU YANG DIPERKUAT EPOKSI BIO-KOMPOSIT SETELAH DIRAWAT PERMUKAANNYA

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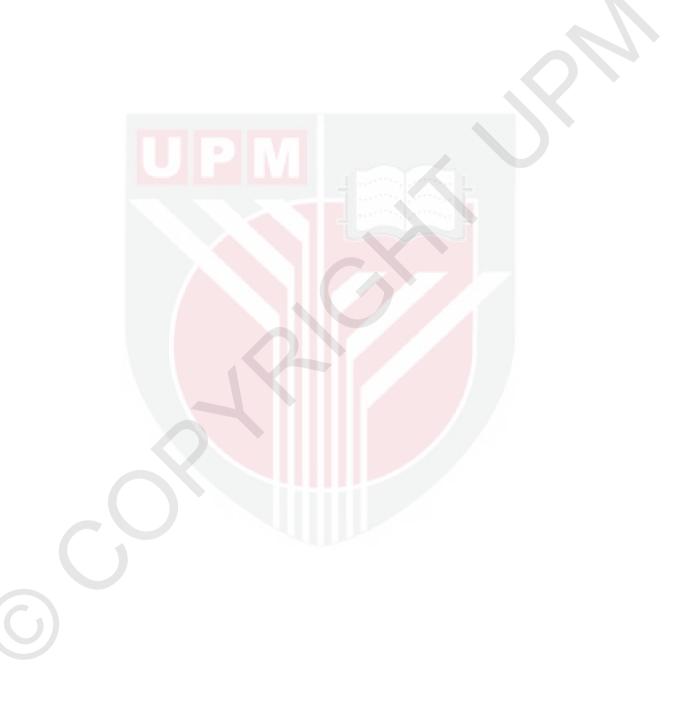
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Beberapa proses rawatan kimia serat semulajadi seperti jut, kenaf, sisal, flux dan lainlain telah diamalkan untuk memperbaiki struktur serat semulajadi itu untuk membantu ia membentuk ikatan yang kuat dengan resin dalam proses membuat bio-komposit. Walau bagaimanapun, bagi serat pokok enau tidak banyak rawatan yang tersedia kerana kurang kajian yang telah dilakukan terhadap serat pokok enau. Hanya sedikit sahaja kaedah rawatan yang boleh didapati untuk serat pokok enau iaitu dengan munggunakan natrium hidroksida (NaOH) dan rawatan air laut. Tesis ini memberi tumpuan kepada kajian rawatan baru untuk serat pokok enau yang merupakan rawatan benzoylation (benzoyl klorida). Tujuan benzoylation adalah untuk mengurangkan sifat hidrofililik dalam serat pokok enau dan memperbaiki ikatan kimia di permukaan serat. Ini membantu serat menjadi lebih serasi dengan matriks polimer dan membentuk ikatan yang kukuh. Sifat mekanikal bagi serat pokok enau yang dirawat dan juga serat yang tidak dirawat telah dikaji. Serat pokok enau dirawat dengan natrium hidroksida dan benzoyl klorida adalah bertujuan untuk mengubah komposisi serat dan untuk memperbaiki sifat-sifatnya. Dalam ujian serat tunggal, penambahbaikan tertinggi dalam kekuatan tegangan diperhatikan dalam serat yang dirawat dengan benzoyl klorida selama 30 minit waktu rendaman dengan kenaikan 47.5 % berbanding dengan serat yang tidak dirawat. Yang kedua tertinggi adalah serat dirawat dengan NaOH, menunjukkan kenaikan 35.1 % berbanding dengan serat yang tidak dirawat. Untuk komposit pula, dengan komposit 30 %, serat yang dirawat dengan NaOH menunjukkan kekuatan tegangan tertinggi dengan nilai 54.8 MPa, diikuti dengan komposit serat yang dirawat dengan benzoyl klorida dengan 54 MPa dan serat terakhir yang tidak dirawat dengan 38.3 MPa. Untuk sifat-sifat terma, proses benzoylation menunjukkan peningkatan yang ketara dalam semua ujian yang dijalankan iaitu analisis termogravimetrik (TGA), analisis mekanik dinamik (DMA), analisis termomekanik (TMA) dan kalori pengimbang perbezaan (DSC). Ini menunjukkan bahawa proses benzoylation memberikan serat dan kompositnya kestabilan terma



yang lebih baik daripada komposit lain. Berdasarkan keputusan yang diperoleh, dapat disimpulkan bahwa kedua-dua rawatan melalui benzoyl klorida dan natrium hidroksida, ia dapat meningkatkan sifat-sifat serat pokok enau dan kompositnya.



ACKNOWLEDGEMENTS

First of all, I am grateful and thanks to Allah S.W.T. by His mercy has given me the opportunity to complete my research project. I would like to thanks my beloved mother and father together with my family for the continuous support and blessing shown towards helping me completing this research project. Not to forget, I am very humbly indebted to chairman of supervisory committee, Dr. Mohamad Ridzwan Bin Ishak and co-supervisor, Dr. Norkhairunnisa Binti Mazlan and Dr. Abdul Malek Bin Ya'acob for their outstanding contribution in advice and assistance throughout this project. Special thanks to Mr. Saffairus Salih, Mr. Ahmad Saifol Abu Samah, Mr. Mohd Azfar Roslan, Mr. Mohd Suhardi Ali, Mrs. Nik Norhafiza Nik Razali, Mrs. Norhaliza Ramli and all staffs from Department of Aerospace Engineering. I also would like to thank Mr. Muhammad Wildan Ilyas Mohamed Ghazali and Mr. Mohd Saiful Azuar Md. Isa from Department of Mechanical and Manufacturing Engineering for their help and assistance with mechanical testing process. Lastly, I would like to acknowledge Dr. Mohd Nurazzi Norizan, Dr. Chandrasekar Muthukumar, Mr. Shahroze, Miss Lee Pay Chiann, Pn. Eli Rashidah Ashari and to all who had helped in completing this research project.

This thesis was submitted to the Senate of the 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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TABLE OF CONTENTS

| | | | Page |
|-------|-------------|---|------------------|
| A DCT | FRAC | Г | ; |
| ABST | | 1 | 1 ii |
| | | LEDGEMENTS | iv |
| | ROVA | | v |
| | LARA' | | vii |
| | | ABLES | xi |
| | | IGURES | xiii |
| | | BBREVIATIONS | XV |
| | | YMBOLS | xvi |
| | | | |
| CHA | PTER | | |
| 1 | INTI | RODUCTION | 1 |
| | 1.1 | Background of the Study | 1 |
| | 1.2 | Problem Statement | 2 |
| | 1.3 | Research Objective | 2 3 3 3 |
| | 1.4 | Hypotheses | 3 |
| | 1.5 | Significance of Study | |
| | 1.6 | Scope and Limitation of Studies | 4 |
| | 1.7 | Structure of Thesis | 4 |
| 2 | LITI | ERATURE REVIEW | 5 |
| | 2.1 | Introduction | 5 5 5 5 |
| | 2.2 | Fibres | 5 |
| | 2.3 | Classification of Fibres | 5 |
| | | 2.3.1 Natural fibres/Bio-fibres Composites | 6 |
| | | 2.3.2 Natural/Biofibres as Reinforcements in | |
| | | Biocomposites | 7 |
| | 2.4 | Sugar Palm Plant and Its Fibres | 9 |
| | 2.5 | Properties of Natural Fibres and Sugar Palm Fibres | 11 |
| | 2.6 | Physical Methods of Surface Modification | 11 |
| | 2.7 | Chemical Method of Surface Modification | 12 |
| | 2.8 | Conclusion | 12 |
| 3 | МЕТ | THODOLOGY | 13 |
| | 3.1 | Introduction | 13 |
| | 3.2 | Experimental Process | 13 |
| | 3.3 | Materials | 15 |
| | | 3.3.1 Preparation of Materials | 15 |
| | 3.4 | Acid and Alkali Treatment | 16 |
| | 3.5 | Testing of Sugar Palm Single Fibre | 17 |
| | | 3.5.1 Structural Analysis of untreated and treated single | |
| | | sugar palm fibre | 17 |
| | | 3.5.2 Morphological analysis of untreated and treated sugar | . – |
| | | palm fibre | 17 |

| | | 3.5.3 Single fibre strength test | 17 |
|--------|-------|---|----|
| | | 3.5.4 Microdroplet test for single sugar palm fibre | 18 |
| | 3.6 | Preparation of Fibre Composite | 20 |
| | 3.7 | Characterization of composites | 23 |
| | | 3.7.1 Tensile test | 23 |
| | | 3.7.2 Flexural test | 24 |
| | | 3.7.3 Dynamic Mechanical Analysis (DMA) | 25 |
| | | 3.7.4 Thermogravimetric analysis (TGA) | 25 |
| | | 3.7.5 Thermomechanical Analysis (TMA) | 25 |
| | | 3.7.6 Differential Scanning Calorimetry (DSC) | 26 |
| 4 | RESU | JLTS AND DISCUSSIONS | 27 |
| | 4.1 | Introduction | 27 |
| | 4.2 | Results for Single Sugar Palm Fibre Test | 27 |
| | | 4.2.1 Tensile test of single sugar palm fibre | 27 |
| | | 4.2.2 Interfacial Shear Strength (IFSS) | 33 |
| | | 4.2.3 FTIR | 35 |
| | 4.3 | Results for Sugar Palm Fibre Composite Test | 37 |
| | | 4.3.1 Tensile Test Result | 37 |
| | | 4.3.1.1 Tensile Stress | 37 |
| | | 4.3.1.2 Young's Modulus | 42 |
| | | 4.3.1.3 Elongation at Break | 45 |
| | | 4.3.1.4 Tensile Stress vs Tensile Strain | 49 |
| | | 4.3.2 Flexural Test Results | 52 |
| | | 4.3.2.1 Maximum Flexural Stress | 53 |
| | | 4.3.2.2 Flexural Modulus | 56 |
| | | 4.3.2.3 Flexural Stress at Break | 60 |
| | | 4.3.2.4 Flexural Stress vs Flexural Strain | 64 |
| | | 4.3.3 Thermal Test Results | 66 |
| | | 4.3.3.1 Thermogravimetric analysis (TGA) | 66 |
| | | 4.3.3.2 Dynamic Mechanical Analysis (DMA) | 69 |
| | | 4.3.3.3 Thermomechanical Analysis (TMA) | 72 |
| | | 4.3.3.4 Differential Scanning Calorimetry (DSC) | 73 |
| | 4.4 | Result Summary | 75 |
| | | 4.4.1 Single Sugar Palm Fibre Properties | 75 |
| | | 4.4.2 Sugar palm fibre composite properties | 75 |
| | 4.5 | Conclusion | 77 |
| 5 | RECO | OMMENDATION | 79 |
| REFE | RENC | ES | 80 |
| BIODA | ATA C | DF STUDENT | 90 |
| LIST (| OF PU | BLICATIONS | 91 |
| | | | |
| | | | |

Х

LIST OF TABLES

| Table | | Page |
|-------|---|------|
| 3.1 | Formulation of fibre loading for untreated and treated sugar palm composite | 21 |
| 4.1 | Analysis of variance table of the tensile strength of different treatment | 28 |
| 4.2 | Duncan multiple range test of tensile strength of different chemical treatments | 29 |
| 4.3 | Analysis of variance table of the tensile modulus of different treatment | 30 |
| 4.4 | Duncan multiple range test of tensile modulus of different chemical treatments | 31 |
| 4.5 | Analysis of variance table of the elongation at break of different treatment | 32 |
| 4.6 | Duncan multiple range test of elongation at break of different chemical treatments | 33 |
| 4.7 | Analysis of variance table of the IFSS of different treatment | 34 |
| 4.8 | Duncan multiple range test of IFSS of different chemical treatments | 34 |
| 4.9 | Analysis of variance table of the tensile strength of different fibres loading | 40 |
| 4.10 | Duncan multiple range test of tensile strength of different fibre loading | 41 |
| 4.11 | Analysis of variance table of the tensile modulus of different fibres loading | 44 |
| 4.12 | Duncan multiple range test of tensile modulus of different fibres loading | 45 |
| 4.13 | Analysis of variance table of tensile strain at break of different fibres loading | 48 |
| 4.14 | Duncan multiple range test of tensile strain at break of different fibres loading | 49 |
| 4.15 | Analysis of variance table of the maximum flexural stress of different fibres loading | 55 |

| 4.16 | Duncan multiple range test of maximum flexural stress of different fibres loading | 56 |
|------|---|----|
| 4.17 | Analysis of variance table of the flexural modulus of different fibres loading | 59 |
| 4.18 | Duncan multiple range test of flexural modulus of different fibres loading | 60 |
| 4.19 | Analysis of variance table of the flexural stress at break of different fibres loading | 62 |
| 4.20 | Duncan multiple range test of flexural stress at break of different fibres loading | 63 |
| 4.21 | Characteristic temperature at elevated weight loss | 67 |
| 4.22 | Coefficient of thermal expansion of untreated and treated SPF composites with epoxy composite | 73 |
| 4.23 | Heat of fusion, ΔH of untreated and treated SPF composites with epoxy composite | 74 |
| 4.24 | Summary results of mechanical test on untreated and treated single sugar palm fibre | 75 |
| 4.25 | Tensile test results of sugar palm fibre composite | 76 |
| 4.26 | Flexural test results of sugar palm fibre composite | 76 |
| 4.27 | Thermal test results of sugar palm fibre composites. | 77 |

C

LIST OF FIGURES

| Figur | e | Page |
|-------|---|------|
| 2.1 | Natural fibres classification [32] | 8 |
| 2.2 | Position of sugar palm fibres on the tree [12] | 10 |
| 3.1 | Flow process of this research | 14 |
| 3.2 | Cleaning process of raw woven sugar palm fibre | 15 |
| 3.3 | Chemical treatment process | 16 |
| 3.4 | Sugar palm fibre prepared for testing | 18 |
| 3.5 | Preparation of interfacial shear strength test (IFSS) | 19 |
| 3.6 | Fabrication of composite process | 20 |
| 3.7 | The universal testing machine used (Instron 3365 test machine) | 23 |
| 3.8 | Samples prepared for flexural test | 25 |
| 4.1 | Tensile stress at maximum load of sugar palm fibre | 28 |
| 4.2 | Tensile Modulus of single sugar palm fibre | 30 |
| 4.3 | Tensile strain at maximum load of untreated and treated sugar palm fibre | 32 |
| 4.4 | Interfacial Shear Strength value of sugar palm single fibre | 34 |
| 4.5 | Fourier Transform Infrared (FTIR) Spectra of untreated and treated sugar palm fibre | 36 |
| 4.6 | Tensile stress of 20 % SPF loading | 38 |
| 4.7 | Tensile stress of 30 % SPF loading | 39 |
| 4.8 | Tensile stress of 40% SPF loading | 40 |
| 4.9 | Young's Modulus of 20% SPF loading | 42 |
| 4.10 | Young's modulus of 30 % SPF loading | 43 |
| 4.11 | Young's modulus of 40% SPF loading | 44 |
| 4.12 | Tensile strain at break of 2 0% SPF loading | 46 |
| 4.13 | Tensile strain at break of 30 % SPF loading | 47 |

| | 4.14 | Tensile strain at break of 40% SPF loading | 48 |
|--|------|--|----|
| | 4.15 | Stress-Strain graph for 20% SPF | 50 |
| | 4.16 | Stress-Strain graph for 30% SPF | 51 |
| | 4.17 | Stress-Strain graph for 40% SPF | 52 |
| | 4.18 | Maximum Flexural Stress for 20% SPF | 53 |
| | 4.19 | Maximum Flexural Stress for 30% SPF | 54 |
| | 4.20 | Maximum Flexural Stress for 40 % SPF | 55 |
| | 4.21 | Flexural modulus of 20% SPF | 57 |
| | 4.22 | Flexural modulus of 30 % SPF | 58 |
| | 4.23 | Flexural modulus of 40 % SPF | 59 |
| | 4.24 | Flexural stress at break for 20 % SPF | 61 |
| | 4.25 | Flexural stress at break for 3 0% SPF | 61 |
| | 4.26 | Flexural stress at break for 40% SPF | 62 |
| | 4.27 | Flexural stress-strain graph for 20 % SPF | 64 |
| | 4.28 | Flexural stress-strain graph for 30 % SPF | 65 |
| | 4.29 | Flexural stress-strain graph for 40 % SPF | 65 |
| | 4.30 | TG of sugar palm fibre before and after chemical treatment with epoxy composite | 67 |
| | 4.31 | DTG of sugar palm fibre before and after chemical treatment with epoxy composite | 68 |
| | 4.32 | Storage modulus curves of epoxy and SPF composites | 69 |
| | 4.33 | Loss modulus curves of epoxy and SPF composites | 70 |
| | 4.34 | Tan delta curves of epoxy and SPF composites | 71 |
| | 4.35 | TMA thermogram showing the behavior of untreated and treated SPF composites with epoxy composite | 72 |
| | 4.36 | DSC thermogram showing the behavior of untreated and treated SPF composites with epoxy composite | 74 |

LIST OF ABBREVIATIONS

| ANOVA | Analysis of variance | |
|-------|--|--|
| ASTM | American Society for Testing and Materials | |
| CTE | Coefficient of Thermal Expansion | |
| DMA | Dynamic Mechanical Analysis | |
| DSC | Differential Scanning Calorimetry | |
| DP | Degree of Polymerization | |
| EFB | Empty Fruit Bunch | |
| FTIR | Fourier Transform Infrared Spectroscopy | |
| IFSS | Interfacial Shear Strength | |
| PE | Polyethylene | |
| POM | Polarized Optical Microscopy | |
| PP | Polypropylene | |
| PVC | Polyvinyl Chloride | |
| SPF | Sugar Palm Fibre | |
| TGA | Thermogravimetric Analysis | |
| TMA | Thermomechanical Analysis | |

LIST OF SYMBOLS

- α alpha
- ρ Density (g/cm³)
- ε Strain (%)
- σ Stress (MPa)
- ΔH Heat of Fusion
- %wt Weight fraction
- F Force (kN)
- E Young's modulus (MPa)
- L Length (m)
- D Diameter (m)
- P Load (N)

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

With the ever-expanding technology in the composites industry, new research have developed in order to find new resource to replace conventional synthetic composites fibre that widely used in many applications [1] [2] with natural composites. With means of changing the method of preparing the composites, engineers can begin to look at the expansion of composites materials industry. The theory behind altering the composition of the mixture of plastic/resin/epoxy with natural resource, is that it will lead to improved properties and/or change the characteristic of the entire composites. The current systems used for composites are that manmade composites can be made from scratch and be form to any desirable properties and characteristic.

For the past few decades, there has been a great deal of research done in the area of composite materials to improve strength of building structures. These structures generally utilize strong materials to support its loads and for creating structures that can increase its lifetime. More recently, the application of natural composites on structures has been implemented in many field such as automotive, and construction site [3] [4] [5] with hopes of many benefits such as reduce the high cost of synthetic composites, improve in performance and reducing waste product of natural resources. The current need in composites industry is a material that can achieve high strength with less weight and less cost with limitless resource such as from recycle materials or waste product from nature. There are certain composite materials that use natural resources as its base (kenaf, flax and chaff) that currently has accomplished its properties, but have certain disadvantages associated with them. There are a few adaptive natural composites that attempt to replicate the properties and behaviour of synthetic composites, such as the high tensile strength, and high modulus of toughness.

Currently, natural fibres are trending among researchers as new resources that can replace synthetic based materials either by itself or with combination from other material to produce green composites. What make it interesting for researcher to applied research on natural fibres are the advantages of natural fibre itself, such as low density, abundance, sustainability, biodegradability, recyclability and low cost which make it more profitable [6]. In evaluating natural fibres, there are some important parameters that should be consider like tensile, thermal and chemical properties. These parameters important in determining the performance of the fibres to be used for composites. In this thesis, sugar palm fibres are used as base for natural composites materials.



1.2 Problem Statement

Man-made fibre known as synthetic fibre are being used widely in almost all industry as reinforcement for composite which have proved its effectiveness over the years. Despite its effectiveness as reinforce for composite, there are many downsides of using synthetic fibre for long term and also short term used of it. The use of synthetic fibre can cause harmful effect toward human and also environment. If someone inhale the synthetic fibre continuously which can happen during the preparation of the fibre itself or when preparing the composite can cause a serious respiratory problem in a long term and damage the lungs of the consumers. As the composite aren't being used or need anymore, the disposable synthetic fibre composite cannot be degraded those will cause pollution and harm the environment [7]. Other than causing damage to the environment and human, synthetic fibre also causing a significant damage to the industrial and corporates industry as the cost of materials and production involving synthetic fibre is very high. With disadvantages of synthetic fibre overwhelm its usefulness, it ignites the sparks of many personnel and also organization to start on new research of finding the replacement for synthetic fibre. The most significant findings from all these researches to replace synthetic fibre are plant fibres. There are many researches that has been done to find the plant fibre that best to replace synthetic fibre for certain use in industry. This is because each plant species produces different fibre thus it makes different properties when mixing with composite which later can be used for different purpose depend of the properties of the fibre composite. However, even with so many researches have been done on many plant fibre, there is one that have the potential to be use as bio fibre composite that have not been study much by researchers and that plant is sugar palm tree. Sugar palm tree or its scientific name refer as Arenga Pinnata has been used from the leaves to the trunk to make into daily product since ancient time. One of it is rope produced from the tree fibre, it being use to tie a small boat to jetty because of its high durability properties towards sea water [8] [9] [10] [11]. These findings have alerted some researcher to study more on the properties and characteristic of the fibre produced by the tree.

There are several researches that has been done on the mechanical properties of the sugar palm fibre composite. Those researches were mainly on the mechanical properties of untreated fibre composite of short, long and woven [7] [12] [13] [14] [15] [16]. Previous studies that had been carried out were using epoxy resin and unsaturated polyester as the matrix. Both matrix used show improvement in the properties of the fibre composite. However, epoxy resin is widely used in aerospace industry than unsaturated polyester due to its properties.

C

For any natural fibre composite to improve its properties, surface modifications of the fibre needed [17] [18] [19]. There are many available methods for natural fibre surface modifications out there but few only been tested for sugar palm fibre. In recent years, many researches unveil the potential of alkaline treatment and sea water treatment on sugar palm fibre properties. However, there is no research carried out to study the potential of using acid treatment on sugar palm fibre for its surface modification. The alkaline and sea water treatment had shown improvement on the tensile and flexural of the sugar palm fibre reinforced epoxy composite.

1.3 Research Objective

The general aim of this study is to determine the mechanical properties, and also thermal properties of treated sugar palm fibre reinforced epoxy composites.

The specific objectives of this study are;

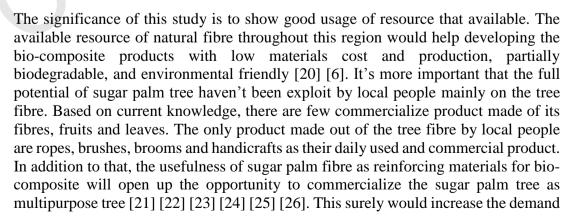
- i. To study the mechanical properties of sugar palm fibre such as tensile strength, and interfacial shear strength (IFSS). To analyse sugar palm fibre component using Fourier-transform infrared spectroscopy (FTIR).
- ii. To investigate the effect of surface treatment using sodium hydroxide and benzoyl chloride on the mechanical and thermal properties of sugar palm fibre and it's composite.
- iii. To analyse the mechanical, and thermal properties of sugar palm fibre reinforced epoxy composite such as tensile properties, flexural properties, and also thermal stability of the composite by using thermogravimetric analysis (TGA), thermomechanical analysis (TMA), dynamic mechanical analysis (DMA) and differential scanning calorimetry (DSC).

1.4 Hypotheses

The hypotheses of these studies are;

- i. There are significant effects of sugar palm fibre content to the mechanical and thermal properties of sugar palm fibre reinforced epoxy composite such as tensile, flexural, TGA, TMA, DMA, and DSC.
- ii. There are significant effects of sodium hydroxide and benzoyl chloride to the mechanical, physical and chemical properties of sugar palm fibre reinforced epoxy composite such as tensile, flexural, TGA, TMA, DMA, and DSC.

1.5 Significance of Study



of the fibre and thus needing more labour in the field and this will open up more work opportunity for local people and increase their income as well [27].

Based on previous researched, sugar palm fibre showed a promising alternative as replacement for synthetic fibre as reinforcing materials in many composite applications such as furniture, doors, and buildings [28] [29] [30].

1.6 Scope and Limitation of Studies

This study focusses on the determination of the mechanical and thermal properties of sugar palm fibre reinforce epoxy composite. The fibre used was in form of unidirectional instead of woven which is its natural form of fibre. The woven fibre obtain from the supplier have to be wash and clean to remove impurities and substance from the fibre before it can be organized properly. The matrix used in this study was epoxy resins and amine hardener. The surface modification used was chemical treatment method by using alkaline and acid. The fibres was treated with alkaline solution using sodium hydroxide (NaOH) and acid solution, benzoyl chloride. The chemical properties in the fibre observed by using FTIR method. Interfacial shear strength (IFSS) were determined by using untreated and chemically treated fibre with the matrix used in the study. Mechanical, physical, and chemical testing were performed in order to determine the composite material properties base on standard requirement. The effect of fibre loading and chemical treatment to the properties of the composite are also studied.

1.7 Structure of Thesis

In this thesis, chapter 1 consist of the background of the study, problem statements, objectives, hypothesis, significance of the study, scope and limitation of the study and structure of the thesis. While for chapter 2 it represents the literature review base on the previous research work in numerous fields of study which are applicable for this research. The literature begins with mostly the latest and later literature survey on natural fibre and sugar palm fibre that are available. Followed by literature on composite and bio-composite. Reviews of its properties are also included in this chapter of study. Chapter 3 describe the methodology of this study in details. It presents the surface modification of sugar palm fibre by chemical treatments method. This chapter also consist of techniques and steps for preparing chemically treated fibre. Besides that, the techniques preparation of composites and determination of its properties (mechanical, physical, and chemical) of sugar palm fibre reinforced epoxy composite also presented in this chapter. Chapter 4 shows the results and discussion on the effects of fibre loadings and chemically treated fibre on the properties (mechanical, physical, and chemical) of the sugar palm fibre reinforced epoxy composites. Lastly, chapter 5 presented the conclusions and also recommendations of future works.

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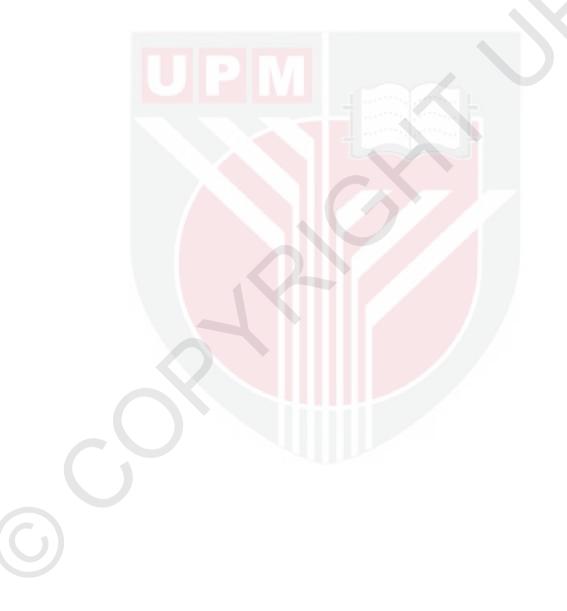
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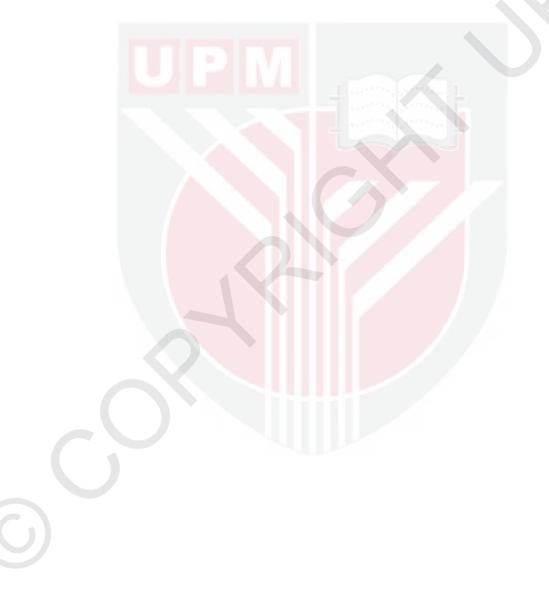
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LIST OF PUBLICATIONS

Journal Paper

A.S. M.Latiff, M.R. Ishak, Norkhairunnisa M., A.M. Ya'acob, Mechanical Properties of Benzoylation Treated Sugar Palm Fiber and Its Composite, International Journal of Recent Technology and Engineering (IJRTE), vol. 8, no. 6, pp. 4248-4252, 2020, Published by Blue Eyes Intelligence Engineering & Sciences Publication, ISSN 2277-3878.

Chapter in book

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