THE MECHANICAL AND PHYSICAL PROPERTIES OF PINEAPPLE LEAF / KENAF FIBRE REINFORCED VINYL ESTER HYBRID COMPOSITES

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DECLARATION

I declare that this project report entitled ‘‘The Mechanical And Physical Properties of Pineapple Leaf / Kenaf Fibre Reinforced Vinyl Ester Hybrid Composites’’ is the result of my own work except as cited in the references

Signature :

Name :

Date :

APPROVAL

I hereby declare that I have this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :

Name of Supervisor:

Date :

DEDICATION

To my beloved mother and father

ABSTRACT

Pineapple leaf fibre and kenaf fibre are natural fibre that can potentially be used as a reinforcement material in polymer composites for different applications. Pineapple leaf fibre seems to be among least studied fibres as reinforcement in composites due to large affinity to water and poor interfacial fibre-matrix adhesion encountered to it. Kenaf bast fibres possess striking mechanical properties. Combination of pineapple leaf fibre and kenaf fibre gives outstanding properties to mechanical and physical properties of the fibre composites. This study investigate the physical, mechanical and also morphological characteristics of pineapple leaf / kenaf fibre reinforced vinyl ester hybrid composites. Several steps have been done to evaluate the physical, mechanical and morphological behavior of natural composite between pineapple leaf fibre and kenaf fibre. Initially, pineapple leaf / kenaf fibre was arranged according to certain parameter. The fibre was treated with alkalization treatment for treated fibre composite and samples were prepared using hand lay-up method. The test conducted to determine physical properties of the pineapple leaf / kenaf fibre reinforced vinyl ester hybrid composite were density, water absorption and moisture content. Tensile test and flexural test were conducted to determine mechanical properties of the hybrid composite. Treated fibre dramatically enhanced most of the properties of vinyl ester hybrid composite. The results revealed that alkalization treatment of fibre changed its chemical properties. The treated fibre improved the physical and mechanical properties of pineapple leaf / kenaf fibre reinforced vinyl ester hybrid composite. The morphological examination of neat polymer, treated and untreated fibre composite-reinforced vinyl esters showed less fibre pull-out from the matrix was observed for treated fibre composite. This observation gives valuable indication of the interfacial interlocking between fibre and matrix which enhanced tensile properties of the composites.

ABSTRAK

Serat daun nanas dan serat kenaf adalah serat semulajadi yang berpotensi digunakan sebagai bahan tetulang dalam polimer komposit untuk aplikasi yang berbeza. Serat daun nanas adalah antara serat yang paling kurang dipelajari sebagai pengukuhan dalam komposit kerana keterlambatan besar kepada air dan perekat serat-matriks yang lemah. Serat kenaf batang mempunyai ciri-ciri mekanik yang menarik. Gabungan serat daun nanas dan serat kenaf memberikan sifat cemerlang kepada sifat mekanik dan fizikal komposit serat. Kajian ini menyiasat ciri-ciri fizikal, mekanikal dan juga morphologi serat daun nenas / kenaf serat bertetulang vinil ester hibrid. Beberapa langkah telah dilakukan untuk menilai tindakbalas fizikal, mekanikal dan morphologi semulajadi antara daun nanas serat dan kenaf serat. Pada mulanya serat daun nanas / kenaf disusun menurut parameter tertentu. Serat ini dirawat dengan rawatan alkali untuk komposit serat dirawat dan sampel telah disediakan dengan menggunakan kaedah pemasangan tangan. Ujian yang dijalankan untuk menentukan sifat fizikal serat daun nanas / kenaf yang diperkuat serat vinil ester hibrid komposit adalah ketumpatan, penyerapan udara dan kandungan lembapan. Ujian tegangan dan ujian lenturan telah dijalankan untuk menentukan sifat mekanik komposit hibrid. Serat yang dirawat secara mendadak meningkatkan sebahagian besar sifat komposit hibrid vinil ester. Hasilnya menunjukkan bahawa rawatan pengalkilan serat mengubah sifat kimianya. Serat yang dirawat meningkatkan sifat fizikal dan mekanikal serat daun nenas / kenaf yang diperkuat dengan komposit vinil ester hybrid. Pemeriksaan morfologi polimer yang kemas, vinil ester yang seratnya dirawat dan serat yang tidak dirawat menunjukkan kurang tarikan serat dari matriks untuk komposit serat yang dirawat. Pemerhatian ini memberikan indikasi yang berharga antara serat dan matrik yang meningkatkan sifat tegangan komposit.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
FRP	Fibre Reinforced Polymer
CAGR	Compound Annual Growth Rate
PALF	Pineapple Leaf Fibre
NaOH	Sodium Hydroxide
KF	Kenaf Fibre
SEM	Scanning Electron Morphology
PMC	Polymer Matrix Composite
CO_2	Carbon Dioxide
WPC	Wood-plastic Composite
Sdn Bhd	Sendirian Berhad
RTP	Room Temperature
Rpm	Rotation per minute
ASTM	American Society for Testing and Material
PC	Polycarbonate
VE	Vinyl ester
PP	Polypropylene

LIST OF SYMBOLS

Symbols	Definition
℃	Degree Celsius
l	Length
w	Width
t	Thickness
ρ	Density
Pa	Pascal
vt	Volume percentage
wt%	Weight percentage
σ	Stress

CHAPTER 1

INTRODUCTION

Introduction part is presented on the first chapter of the project report which consist of project overview, problem statement, objective and scope of project.

1.1 Overview of the Project

Natural fibre possess a crucial concern in developing fibre reinforced polymer (FRP) composite to conclude the present ecological and environmental issue. Lucintel released a market report that told global natural fibre composite material market is increasing at a Compound Annual Growth Rate (CAGR) of 8.2% from 2015 to 2020 (M. Asim *et al.*, 2018). There is concern in bio-based materials especially natural fibre reinforced composites that correspond not only with legislation popularized in wide markets such as European Union (Directive 2000/53/EC) but with the priority of many major automakers' interest in global sustainability. The industries demand a lower price for production of fibre components at the same time with an improvement in quality as there is high price in composites (Arib *et al.*, 2006). In order to resolve the ongoing ecological and environmental issues, natural fibres could show a meaningful part in establishing biodegradable composite (Kasim *et al.*, 2013).

Natural fibres especially sisal, jute, banana, coir and pineapple captivated the attention of materials scientists and technologists for purpose of consumer goods, reasonable structural materials and automotive parts. Natural fibre also have low density, renewable and biodegradable (Udaya Kumar *et al.*, 2018). The natural fibre which has magnificent potential to be passed down as reinforcing materials in green composite product are pineapple leaf fibre (PALF) and kenaf fibre (KF).

Pineapple leaf fibre was chosen as natural fibre used in this research in the interest of comparatively better mechanical properties, accessible and economical than the established natural fibre such as kenaf and jute (Kasim *et al.*, 2013). The manufactory treats pineapple leaves as agricultural wastes formed or burnt by country person after the fruits are harvested when focusing on the fruits and related foodstuffs (Mohamed, Sapuan and Khalina, 2014). Already well-known in Malaysia as well as South-East Asia is kenaf fibre (M Asim *et al.*, 2018) where possessing flexural strength combined with its outstanding tensile strength caused kenaf bast fibre as material of choice for a wide range of extruded, molded and non-woven products (Aji *et al.*, 2009).

In this research, mechanical and physical properties of pineapple leaf fibre / kenaf fibre reinforced vinyl ester hybrid composites will be analysed. The outcomes were used to enhance the perceptive of PALF and KF and their need as reinforcement in vinyl ester hybrid composites in the attempt to employ these outstanding fibres.

1.2 Problem Statement

Environmental pollution, waste disposal troubles as well as ecological matter with heavy in weight and non-biodegradable are the most crucial problems of current plastic materials (Samylingam, 2015). By being cost effective, natural fibre is biodegradability for its most important property to replace non-renewable and expensive synthetic fibre (M. Asim, Khalina Abdan, M. Jawaid, M. Nasir, Zahra Dashtizadeh, M. R. Ishak, 2015). Composite materials which consists of carbon fibres and glass fibres have outstanding mechanical properties but due to the non-degradability of fibres, these materials caused environmental pollution (Saba, Paridah and Jawaid, 2015). Synthetic fibres could cause skin irritation which is dangerous to human health if it is not handled properly (Mohd Nurazzi, Khalina, Sapuan, Dayang Laila, 2017).

Financially pineapple leaves are treated as waste materials of fruits which is being used for producing natural fibres (Yogesh and Rao, 2018). From literature, there is lack of data reported on PALF-VE hybrid composites (Yogesh and Rao, 2018), (Mohamed, Sapuan and Khalina, 2014). Besides, PALF also occupy essential complications such as poor interfacial fibre-matrix adhesion and immense affinity to water which prohibit their use reinforcement in composites (Mohamed, Sapuan and Khalina, 2014). The high cellulose content and comparatively low microfibrillar angle are associated with superior mechanical properties of pineapple fibre (Devi, Bhagawan and Thomas, 1996).

Kenaf can be defined as robust mechanical properties as it exhibits low density, biodegradability and have high specific mechanical properties with non-abrasiveness during processing (Aji *et al.*, 2009). As a replacement to glass fibres in polymer composites, kenaf bast fibres possess striking mechanical properties (Saba, Paridah and Jawaid, 2015).

Most of the problem reported from literature is the weakness of interfacial bonding between fibre and polymer. In order to overcome this type of problem, chemical treatment is the solution.

1.3 Objective

The objective of this project are as follows:

i. To investigate tensile and flexural strength of pineapple leaf fibre / kenaf fibre reinforced vinyl ester hybrid composites.

ii. To study physical properties in terms of density, water absorption and moisture content of hybrid fibre composites.

iii. To investigate the morphological properties of pineapple leaf fibre and kenaf fibre reinforced vinyl ester hybrid composites.

1.4 Scope of Project

The scope of this project is to develop hybrid composites of vinyl ester resin. Next, conduct investigation on the mechanical and physical properties of pineapple leaf fibre/ kenaf fibre hybrid composites. Finally, conduct the microstructure analysis of failure samples by using scanning electron microscopy. The experiments were conducted in Fasa B and Amchal Lab, Malacca.

The scopes of the projects are as follows:

i. Study of mechanical properties in terms of tensile strength and flexural strength.
ii. Study of physical properties in terms of density, water absorption and moisture content.
iii. Microstructure analysis on PALF/KF reinforced VE hybrid composite.

The PALF were treated with sodium hydroxide (NaOH) for treated fibre. Finally, the fibre was blended with vinyl ester resin to form composite samples. The methodology in this research is experimental investigation. The research was divided into two different phases.

First phase of this project focuses on the effect of different surface treatments and fibre loading of pineapple leaf and kenaf. This is the critical part of the project where the properties were discussed and observed thoroughly. The chemical treatments were used to differentiate between neat fibre, untreated fibre composite and treated fibre composite. The sample underwent two testing in order to check the properties of the hybrid fibres which are physical and mechanical properties. The tensile test failure samples will undergo SEM for morphological analysis to evaluate the fibre distribution and fibre bonding with the resin.

Second phase of the project is evaluation of the obtained results. The optimum results of mechanical and physical properties of PALF/KF reinforced vinyl ester hybrid composites will be highlighted and discussed further.

CHAPTER 2

LITERATURE REVIEW

The second chapter encompasses reviews of literature which is relevant to the scope obtained from journals, books and website. There is discussion on development of natural fibres as well as pineapple leaf fibre and kenaf fibre as reinforcement material. By using natural fibres as an alternative, reviews on previous research gives desired findings and rational of the study which also explains on performances of natural fibres.

2.1 Natural Fibre Composite

Developing countries are leading to discovery and development of natural materials as there is an increased pressure from environmental activists (Jawaid and Khalil, 2015) where acute irritation of skin, eyes and respiratory tract caused by use of glass fibre creates anxiety for development of cancer and lung scarring. Glass fibre does not deteriorate when released and endanger animal life and nature (M. R. Ishak, Z. Leman, S. M. Sapuan, 2010). Glass fibre also had higher density which is 2.4 g/cm^3 compared to natural fibre that is more lighter for about 1.2-1.6 g/cm^3 which provide lightweight composites (Akil *et al.*, 2011) and also gives higher specific strength for natural fibres. In the aerospace, automotive and wind energy industries, synthetic fibres had been used that gives environmental issue include consumption of energy during production and difficult to dispose its product (Ismail et al., 2019).

Scientists and manufacturer were fascinated towards natural fibres for having better formability, renewable, abundant, and cost effective, possess tool wearing rates and sufficient energy requirements (Saba, Paridah and Jawaid, 2015). Natural fibres also had good tensile properties which also low density, recyclable and eco-friendly material. Developing suitable techniques to obtain good quality fibres for reinforcement of polymer composites, researcher was challenged to provide utilization of natural fibres in industrial application (Samylingam, 2015). In order to ensure long-term sustainability for farmers who rely heavily on their production, there was raising global awareness about natural fibres with particular focus on increasing market demand. There is an increasing interest in maximizing use of renewable materials in order to solve future petroleum shortages and dependence on petroleum products and reduce environmental impact of materials (Aziz, 2011).

Captivated in natural fibre composites was progressing as natural fibre composites had potential to change synthetic fibre reinforced plastics at smaller amount with progressed sustainabiliy (Pickering, Efendy and Le, 2016). Natural fibre composites have been used in applications as diverse as toys, funeral articles, packaging, marine railings and cases for electronic devices such as laptops and mobile phones as a replacement for synthetic fibre There is uniqueness of the mechanical and dielectric properties of natural fibre composite that also support environmental advantages (Kasim *et al.*, 2013).

Natural fibre was similar to pieces of thread that are in continuous filaments or in discrete elongated pieces which could be spun into filaments, rope or thread. Those grown for their fibre content was primary plants while secondary plants was plants in which by-product was produced by fibre. The examples of primary plants were hemp, kenaf, sisal and jute while secondary plants were oil palm, pineapple and coir (Faruk et al., 2012). The moisture content of plant fibres reaches 8 – 13% as of its hydrophilic nature where these hydroxyls formed hydrogen bond with hydroxyl groups from air and inside macro-molecules (intermolecular) (Jawaid and Khalil, 2015).

In order to achieve high performance of composites, high fibre content is required. It was often observed that increase in tensile properties was due to increase in fibre loading (Ku *et al.*, 2011). High tensile strength was given by intrinsic properties such as low microfibrillar angle and high content of cellulose (Aji *et al.*, 2012). Producible with low investment and could act as a good replacement to synthetic fibre, natural fibre had become a popular alternative as a reinforcement fibre. A plant fibre embedded within a thermoset or thermoplastic polymer was brief definition of natural fibre composites (Mohd Nurazzi, Khalina, Sapuan, Dayang Laila, 2017).

Chemical composition and structure of the fibre is depending on growing conditions, harvesting time, extraction method, treatment and storage procedures.. Although stiffness can be achieved with natural fibres compared to glass fibre, strength and stiffness of natural fibres are generally lower than glass fibre. Nevertheless, natural fibre had higher specific Young's Modulus and specific tensile strength than Electric-glass fibre (Pickering, Efendy and Le, 2016).

However, disadvantage by the usage of natural fibres as reinforcement material in polymer composites are tendency to form aggregates during processing, poor moisture resistance, incompatibility between fibres and polymer matrices, lower durability, limited processing temperatures, inferior fire resistance and variation in quality and price as well as difficulty in using established manufacturing process. Compared to glass or carbon fibre composites, incompatibility between natural fibres and polymer matrices leads to low interface strength. This is because natural fibres was hydrophilic in nature derive from lignocellulose as there was presence of hydroxyl groups which is incompatible with hydrophobic polymer matrix such as polyolefin (John and Anandjiwala, 2008). High moisture absorption of fibres indicated hydrophilicity of natural fibres and produced composites failure in wet conditions due to fibre swelling. Poor process ability and low mechanical performance of composite were led due to presence of moisture during manufacturing. To process thermoplastics with processing temperature higher than 200℃, majority of natural fibres have low degradation temperature which was inadequate. Through surface treatments, resins, additives or coatings by interfacial treatments, this condition could be improve (Azwa *et al.*, 2013).

2.2 Pineapple Leaf Fibre Composite

One of the most essential tropical fruit is *Ananas comosus* which is also called pineapple in the world besides banana and citrus (M. Asim, Khalina Abdan, M. Jawaid, M. Nasir, Zahra Dashtizadeh, M. R. Ishak, 2015). Malaysia is one of the largest pineapple cultivation. From literature, the pineapple leaves are about 384,673 metric tonnes in year 2008 were tossed that contribute waste pollution which then burn (Kasim et al., 2013). Environmental pollution such as haze was caused by the burning process of pineapple leaves (Mohamed, Sapuan and Khalina, 2014). To replace glass fibre in low priced product especially for construction purpose, PALF was being identified (L. A. Samylingam, 2015).

PALF seems to be among least studied fibres as reinforcement in composites due to large affinity to water and poor interfacial fibre-matrix adhesion encountered to it (Mohamed, Sapuan and Khalina, 2010). There has been no work reported on PALF-VE composites by literature and bibliographic search. Tensile strength and flexural strength was some of the highest mechanical properties obtained by pineapple leaf fibre. By increasing PALF weight fraction, density of PALF-reinforced composites were vary due to difficulty in properly distributing fibres within matrix. Besides that, there is large amount of voids which lead to lower specific gravities by using hand lay-up method.

Due to the limitation of data, PALF is still not fully utilised although it have excellent mechanical strength and develop a good chemical composition. Dependant on length of fibre, matrix ratio and fibre arrangement were physical and mechanical properties. 10% of volume percentage of PALF increased in total deformation (Oliveira *et al.*, 2017). PALF does not make good bonding with hydrophobic matrix especially at high temperatures as PALF is hydrophilic. Thus, chemical treatment with NaOH can minimize water absorption and improves mechanical properties between PALF and polymer. Less moisture content was shown by chemically modified PALF-reinforced low density polyethylene (LDPE) (M. Asim, Khalina Abdan, M. Jawaid, M. Nasir, Zahra Dashtizadeh, M. R. Ishak, 2015).

Yarns of the PALF were used to construct fabrics, mops, curtains and fancy carpets (Mishra *et al.*, 2004). In a wet condition, yarn strength increases about 13% while PALF decreases by 50%. There is a uniform sharing of load in ultimate fibres of raw pineapple leaf while treated leaf displays uneven fractures portrayed by slippage of individual ultimate fibres. Compared to neat PALF, all composites shown higher tensile and flexural modulus in mechanical test. upon addition of PALF, value of strength increase (Siakeng *et al.*, 2018).

There is very little work done on mechanical properties of PALF due to lack of adequate knowledge on physical and chemical properties of the fibre. Treatment with NaOH solution indicates removal of hemicelluloses where tensile strength of PALF decreases (John Wiley & Sons, 1993). Bruise or dimensional deformity can be caused by high moisture content in fibre that affect physical and mechanical properties of the final product(Asim *et al.*, 2015).. Water molecules face barriers by stiffness of polymer chain segments at low temperature. Factors such as molecular structure, polarity, crystallinity and hardeners will determine the spread of humidity into a polymer in the manufacture of composites.