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

This report is submitted
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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**
°C	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.

2.3 Kenaf Fibre Composite

Scientifically named Hibiscus Cannabinus L, kenaf was environmental friendly and biodegradable crop (Thiruchitrambalam, Alavudeen and Venkateshwaran, 2012). **Figure 2.1** below shows kenaf plant that was known as a cellulosic source (Akil et al., 2011). Kenaf has great adaptability and easy to handle compared to allied fibre crops. Hardy, strong and tough plant with fibrous stalk was definition of kenaf plant where there is fewer amount of pesticide and also resistant to insect damage. Kenaf plant had three types of fibre which are bast, core and pith (Saba, Paridah and Jawaid, 2015).

Figure 2.1: Kenaf plant.

Kenaf fibre was potential in economist, market research, leading to collaboration between R&D and manufacture of newsprint and other paper product where interest to this good fibre was increased (Saba, Paridah and Jawaid, 2015). Besides that, the fibre are also used for commercial products such as fibre lawn mats impregnated with grass seed and spray on soil mulches along highway or for construction sites to avoid erosion of soil from water and wind. In automotive industry, kenaf fibre was used to made interior automobile panels in 1996 Ford Mondeo (L. A. Samylingam, 2015).

Kenaf fibre from the bast and core were extracted from the bark of the tree. As high as 60.8% was the cellulose content from kenaf bast fibre while core fibre had about 50.6% cellulose content. Kenaf bast fibre strands was used to produce rope, automobile dashboards, paper, textiles and as fibres for extruded plastics as this fibre had potential to replace glass fibre which is synthetic in polymer composites. 40% fibre loading was considered as optimum condition in polymer composite which give better mechanical properties although there was no clear trend on how much fibre loading could give better mechanical properties (G. Faruq, M. A. Alamgir, M. M. Rahman, M. R. Motior, H. P. Zakaria, 2013).

Due to global environmental issues and inadequate raw fibre resources, scientists have developed utilization of kenaf in reducing soil erosion due to wind and water, toxic waste cleanup, removal of oil spills on water, replacement or reduced use of fibre glass in industrial products and increased use of recycled plastics and paper quality. Kenaf was environmentally friendly because of absorbs nitrogen and phosphorus from soil and also accumulates carbon dioxide at significantly high rate (Aziz, 2011). Exhibit good mechanical properties and can grow quickly, kenaf could rise to height 4-5 meter within 4 to 5 months growing season. Thus, kenaf fibre composite which takes only 150 days to harvest was given chance to develop products similar to wood material. This will help to prevent deforestation as demand on timber reduced (M. R. Ishak, Z. Leman, S. M. Sapuan, 2010).

Figure 2.2 below shows physical appearances of kenaf fibre to get a better view of this plant (Aji et al., 2009).

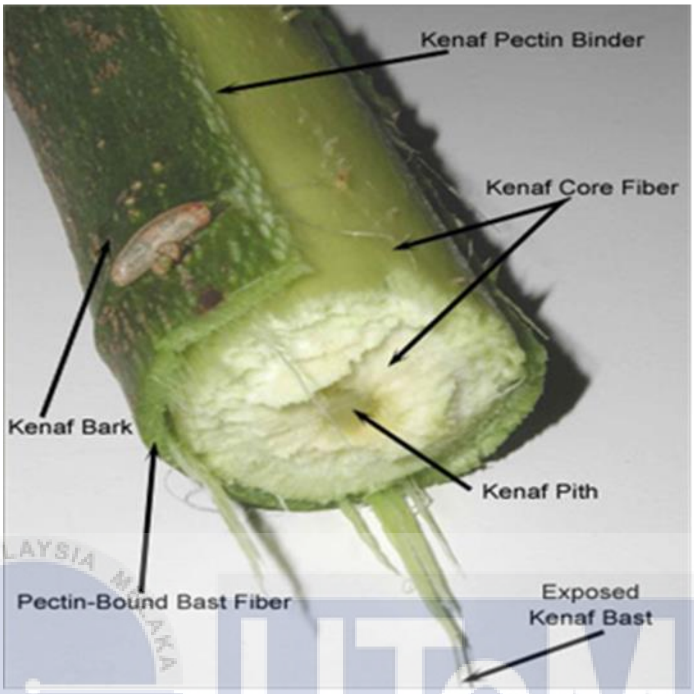

Figure 2.2: Physical appearances of kenaf fibre.

Automative head liner were successfully fabricated by implementation of kenaf/ramie hybrid composies. The increase of strain rate, tensile strength of the kenaf fibre bundle also increases while tensile modulus remain unchanged. In kenaf fibre reinforced poly lactic acid composite, the higher the content of fibre, the higher the flexural properties of composite. It was also reported that in 4 weeks of composting, 38% of weight reduces. Tensile strength and modulus increases with the addition of long kenaf fibre as reinforcement with wood flour and polypropylene composite. Optimum fibre content was 20% wt for bast and core fibre as achieving highest tensile strength (M. R. Ishak, Z. Leman, S. M. Sapuan, 2010). It was also shown that as fibre content increased, the elongation at break for both composites decreased. Optimum fibre content for flexural strength was 10% wt.

Absorbents and animal bedding which have more ready markets were obtained from kenaf core materials (Rashdi *et al.*, 2009). Superior toughness and high aspect ratio of kenaf bast fibre was known to have potential as a reinforcing fibre in thermoplastic composites. Lack of good interfacial adhesion between kenaf fibre and polymer matrix resulted in poor properties in final product. On the surface of kenaf fibre, as hydrogen bonds of fibre surface tend to prevent wetting of filler surface, polar hydroxyl group had difficulty to form a well bonded interphase with a relative non-polar matrix.

2.4 Pineapple Leaf / Kenaf Fibre Reinforced Vinyl Ester Hybrid Composite

2.4.1 Hybrid Composite

Definition of hybrid is adding two different types of material into one single material (Kretsis, 1987). Properties of polymers were improve by reinforcing them with various treated fibres, particulate fillers and combine two fibres and results in hybridization as polymeric resin exhibit poor mechanical properties (P.A. Udaya Kumar, Ramalingaiah, B. Suresha, 2018).

Hybrid composite was used as one type of fibre could complement the other fibre lacking (Jawaid and Khalil, 2015). Dependent on properties of fibre, aspect ratio of fibre content, individual length of fibre, fibre orientation and arrangement of two fibre and also failure strain of individual fibre were the strength of hybrid composites. When fibres are highly strain compatible, maximum hybrid results were obtained. Arrangement of hybrid will terminate moisture absorption into composite and filling up voids with the pack arrangement of fibre which happened during formation of composite. Composites was enabled to take up a high amount of moisture from surrounding environment due to hydrophilic nature of cellulosic materials. When the samples were soaked into the water, hydrophilic properties of cellulosic materials and capillary action will caused intake of water and increase dimension of composite. This will affect the thickness of swelling. Coir based hybrid composite shows that increasing fibre content also increased tensile properties (Kumar, Reddy, Naidu, Rani, & Subha, 2009). Alkali treatment of coir based composites also show significant improvement.

PALF that has high cellulose content and soft while KF was commercially available natural fibre to use as reinforcing material and comparatively very cheap. Compare to untreated hybrid composite, treated PALF and KF showed very good mechanical properties and the interfacial stress strength was extremely high. Treated PALF/KF phenolic hybrid composites which were fabricated by hand lay-up method enhanced flexural strength although tensile strength and modulus decreased (Asim et al., 2017). Hybrid composites which had fibre surface modification significantly increased mechanical properties and reduced hydrophilicity.

The improvement in mechanical properties of KF/wood flour reinforced polypropylene hybrid composite after adding maximum proportion of KF (M Asim, Jawaid, et al., 2018). Besides, woven kenaf / Kevlar reinforced epoxy hybrid composite also portrayed better mechanical properties by using hand lay-up method. By (Sapuan, 2013), fibres of KF and PALF was at ratio of 1:1. Due to good fibre/matrix interfacial bonding, treated 50% fibre loading KF/PALF reinforced phenolic composites showed better mechanical properties (Jawaid and Ishak, 2017). Untreated PALF/KF hybrid composites, treated PALF/KF reinforced phenolic hybrid composites enhanced dynamic and thermal mechanical properties (M Asim, Paridah, et al., 2018). Combination of the strength and compatibility of PALF and KF to each other was encouraged as KF was already well known in Malaysia while PALF was underutilized material which can be commercialized after projecting it as reinforced material.

Hybridization effect of KF/PALF was optimized for tensile and flexural test at equal percentage ratio of fibre when total overall fibre loading in composite was kept at 40% (Aji, Zainudin, Abdan, et al., 2012). KF provide impact strength and reduction of water intake while PALF helps in tensile and flexural properties. As KF has higher aspect ratio, there was better stress transfer from matrix to fibre. Furthermore, at contant fibre loading of 40%, the ratio of the hybrid composite was equal at 1:1 (Aji, Zainudin, Sapuan, et al., 2012).

The applications such as food packaging and structure components to reduce environmental loads, hybrid composite containing coir fibre and PALF in a ratio 1:1 ratio (C1P1) presented optimum set of mechanical properties and improved thermal stability (Siakeng et al., 2018). In composite technology, hybridization was a method to overcome drawbacks of natural fibre such as poor interfacial adhesion and high moisture absorption which also for obtaining natural/synthetic fibre-reinforced polymer composites with good mechanical and thermal properties. Hybrid polymer materials was potentially positive materials with respect to environmental concerns although it is not very common (Siakeng et al., 2018). After coir fibre treated with NaOH solutions, a significant improvement in tensile, flexural and compressive strengths were obtained. Besides, ability of coir fibre to dissipate impact energy improve upon reinforcement with coir fibre in polyester hybrid composites. Other than that, upon addition of fibres, there is improvement in properties for PALF/KF reinforced phenolic resin hybrid composites.

2.4.2 Vinyl Ester Resin

There are two type of polymer which are thermoplastics and thermosetting. Polypropylene (PP), polyethylene and poly vinyl chloride (PVC) are examples of thermoplastics while for thermosetting matrices are vinyl ester, epoxy and polyester resin (Ku et al., 2011). Vinyl ester are flexible, strong and less hydrophilic in nature although in PALF reinforced VE composites, there was not much literature available. Tough, resilient and less susceptible to water degradation by hydrolysis was expected by vinyl ester (Mohamed, Sapuan and Khalina, 2010).

Real composites produced by using untreated PALF reinforced with vinyl ester demonstrates the enhancement of PALF's vinyl ester composite properties, particularly their water resistance (Mohamed, Sapuan and Khalina, 2010). Due to fibres serving mainly as defects attributed to poor specimen preparation, it was not confirmed that adding low amount of PALF jeopardized mechanical properties of VE. For examples, at 14.6 wt% PALF, as much as 26% was improved in tensile modulus of PALF reinforced VE. Thus, using untreated PALF reinforced VE resin to produce real composite is viable.

Particulate filler content and void fractions in composites increases with increase of PALF-VE composites. Micro hardness of PALF-VE composites improve with the presence of particulate fillers (Yogesh and Rao, 2018).

2.5 Alkaline Treatment on Hybrid Composite

Mechanical behavior of composites could be improved by using alkaline treatment. This treatment was shown to efficiently removed non-cellulosic materials such as lignin and hemicellulose and improve tensile strength of date palm fibres (Oushabi *et al.*, 2017). Compared to untreated one, treated fibre improved tensile strength of the composite where impurities such as wax and oil were removed completely without damaging surface of fibre. Surface of the fibre also became rough which enhances mechanical interlocking adhesion between matrix and fibre. High alkali concentration such as 10 wt% NaOH solution will caused damage in surface topography.

The increasing concentration of alkali improve mechanical properties of composite (Thiruchitrambalam, Alavudeen and Venkateshwaran, 2012). With the use of 6% NaOH solution, an alkali surface treatment of fibre was done (Rashdi *et al.*, 2009). Alkali treatment remove hydrogen bonding in network structure (John and Anandjiwala, 2008). In treated fibre, the amount of surface impurities decreased. Compared with untreated fibre composite, surface modification would enhanced adhesion and tensile properties.

One of the most widely used chemical treatments for natural fibre was alkaline treatment especially when using KF reinforcing thermosets and thermoplastics. For a period of time, the fibre will immersed in NaOH solution where this treatment removes lignin, wax, oils and hemicellulose that cover external surface of fibre cell wall (Akil *et al.*, 2011). The treatment would increase aspect ratio and fibre diameter will be reduced. Insufficient filling of matrix resin was due to decrease in mechanical properties of composite in fibre content above 70 vol %. The strength and stiffness was lasting effect of alkaline treatment on mechanical behavior.

By doing chemical treatment, surface of fibre will be chemically modified and clean, reduce absorption process and upsurge surface unevenness (Saba, Paridah and Jawaid, 2015). Mechanical properties of KF was improved by alkalization treatment with sodium hydroxide compared to untreated KF with optimum value of 6% NaOH which shows good results for method of chemical treatment. If 6% optimum concentration of alkaline was used, chemical treatment of fibre can chemically modify surface, stop moisture absorption process, increase surface roughness and clean the fibre surface (Aji *et al.*, 2009).

CHAPTER 3

METHODOLOGY

Chapter three represents methodology of the project which covered on the method for sample preparation of pineapple leaf fibre and kenaf fibre. Furthermore, the materials and method used for the testing of the hybrid composite will be described.

3.1 Material

3.1.1 Pineapple Leaf Fibre

The crucial factor in this project is pineapple leaf fibre as PALF will be a part of the sample used in the experiment for natural fibre composite. Pineapple leaf fibre was acquired at plantation site from Kota Tinggi-Mersing, Johor. **Figure 3.1** shows the pineapple leaf fibre in the form of yarn which is used in the project.

Figure 3.1: Pineapple leaf fibre.

3.1.2 Kenaf Fibre

Kenaf fibre was in the form of powder received from Lembaga Kenaf dan Temabakau Negara, Kedah. **Figure 3.2** below shows kenaf fibre in the form of powder. The powder used in the kenaf fibre was kenaf bast.

Figure 3.2: Kenaf bast fibre.

3.1.3 Vinyl Ester Resin

Vinyl ester resin was used for the thermosetting resin in this project. A company named Polymer Technology Pte Ltd (Singapore) was where VE was obtained. The properties of 1.6 g/cc, 120°C, 400cP and 104.44 to 143.33°C was the density, heat distortion temperature (HDT), viscosity and glass transition temperature of VE respectively. Industry always apply vinyl ester in anti-corrosion parts such as pipes, tanks, containers and floor coverings. **Figure 3.3** shows vinyl ester in a tin.

Figure 3.3: Vinyl ester resin.

3.1.4 Sodium Hydroxide Pellets

To prepare NaOH solution for the alkali treatment process for treated fibre composite, sodium hydroxide pellets 99% grade was obtained from QRac (Asia) Sdn. Bhd., Malaysia. The highly soluble in water and a few polar solvents such as ethanol and methanol are inorganic compounds that can be found in NaOH pellets. Exothermic reaction will be produced from the dissolution of these pellets in the water where the solution are colourless and odourless. **Figure 3.4** below shows NaOH pellets that is white in colour and round in shape.

Figure 3.4 : NaOH pellets.

3.2 Material Characterization

In this project, the sample of PALF/KF reinforced with vinyl ester hybrid composite was made from wet hand lay-up method. The PALF/KF were prepared according to the composition given.

3.2.1 Mold Preparation

The fabrication of PALF/KF hybrid composites was carried out through hand lay-up method. The mold used to prepare the hybrid composite was made from rectangular steel plates brought at Ayer Keroh, Melaka. The mold plates had 3mm thickness all around it. The plates were used to cover the reinforcement of the hybrid composites after vinyl ester is smeared. **Figure 3.5** below shows rectangle mold that was used in the experiment.

Figure 3.5 : Rectangular mold for composite.

3.2.2 Chemical Treatment of the Fibre

The pineapple leaf fibre obtained in the form of yarn was manually cut into 1cm of length. Kenaf and PALF were mixed together during the sample preparation. The fibre will then undergone an alkaline process for treated PALF/KF hybrid composite later as shown in **Figure 3.6** . 6 wt% NaOH solution was prepared by 6g of sodium hydroxide pellets dissolved in 940ml distilled water at room temperature (RTP). For twenty four hours at RTP, the fibres were immersed in NaOH solution in a basin. The fibres were then washed with running water thoroughly and dried at RTP for 24 hours, so that moisture will be eliminated from the fibres. From literature, the fibres were put in the oven at 104℃ to remove water molecules in the samples for 24 hours after dried at room temperature.

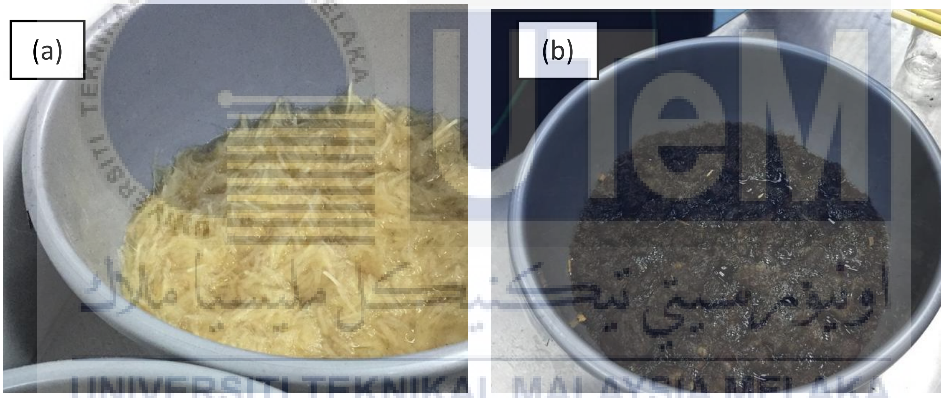

Figure 3.6 (a) and (b): Pineapple leaf fibre, Kenaf fibre

3.2.3 Fabrication of Composite

Pineapple leaf /kenaf fibre reinforced vinyl ester hybrid composites were fabricated by using wet hand lay-up method. Three sample have been fabricated in this project. Neat polymer, PALF / KF hybrid composites (treated fibre and untreated fibre).

For neat polymer, the vinyl ester resin were weighed for 150g. Methy ethyl ketone peroxide (MEKP) were mix together with the resin for the sample and stirred until the bubbles formed in the mixing disappear. The mixing were poured in the mold and then cured for 24 hours at RTP as shown in **Figure 3.7.**

For hybrid sample (treated and untreated) **in Figure 3.8**, 5 wt% of PALF/KF were mixed together with the resin. In this project, 5 wt% of the fibre was used as reinforcement material (Nadlene Razali, S. M. Sapuan, Mohammad Jawaid, 2016). The ratio used is 1:1. First of all, VE were mixed with MEKP. PALF/KF were gradually put in the resin and stirred until the mixture was uniformly distributed using a mechanical stirrer at 100 to 250rpm. Total weight of fibre composite sample was 150g. About 3g of MEKP was used in the composite. The mixture was stirred for about 20 minutes. Then, the mixture of PALF/KF and VE was poured into the mold and cured for 24 hours at RTP. **Figure 3.9** show the untreated and treated fibre composite after cured.

Finally, the samples were cut into specific dimensions according to ASTM standard for tensile and flexural test. Then, the fibres were cut into smaller pieces for the use of density, moisture content and for water absorption.

Figure 3.7 : Sample preparation of neat polymer.

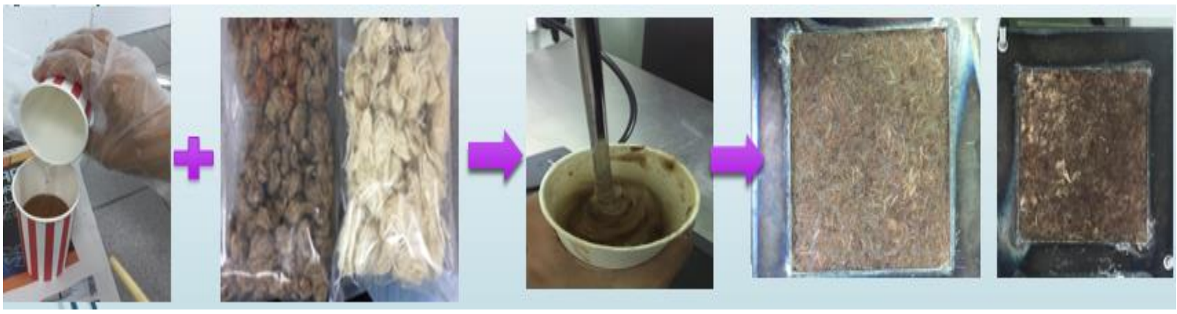

Figure 3.8: Sample preparation of fibre composite.

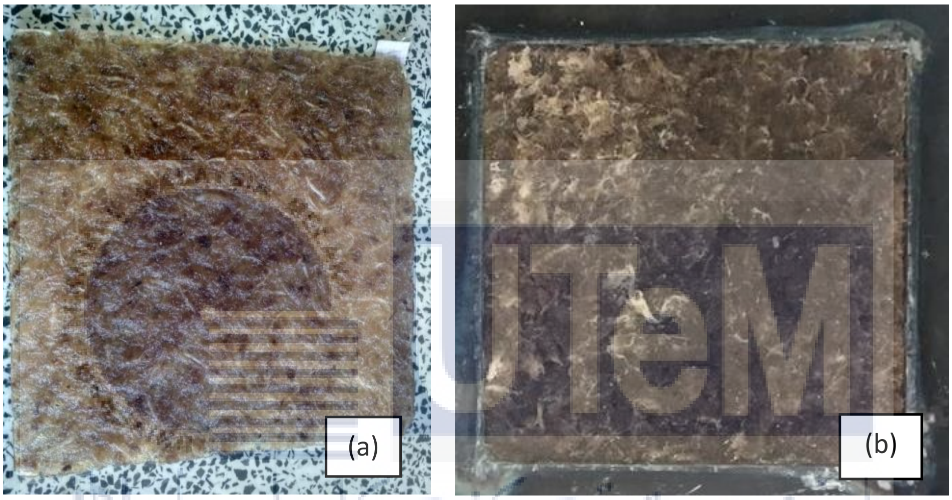

Figure 3.9 (a) and (b): Untreated fibre composite, Treated fibre composite.

3.3 Characterization and Material Testing

Testing is important to figure out the properties and behavior of the sample. There are several testing that need to be carried out to characterize the properties of the samples in term of physical, mechanical and morphological testing. **Table 3.1** below shows detail of testing that will be carried out on the hybrid composite samples.

Table 3.1 : Sample testing method.

Physical Testing	Mechanical Testing	Morphological Testing
Density	Tensile	Scanning Electron Microscope (SEM)
Water Absorption	Flexural	-
Moisture Content	Impact	-

3.3.1 Determination of Moisture Content

Five samples of each treatment were cut into 10mm (length) x 10mm (width) x 3mm (thickness) for the evaluation of moisture content according to ASTM D5229. The absorption of moisture in PALF/KF is closely related to air humidity as natural fibre is hydrophilic in nature. For example, the higher the moisture content in those fibre, the higher the humidity. Based on the **Equation 3.1** below, the percentage of the moisture content can be calculated. In the oven at temperature of 110°C, the sample will be heated for 24 hours. M_0 can be referred as the weight of samples that were taken before being heated in the oven. Meanwhile, M_1 can be referred as the samples that were weighed again to get the mass after being heated in the oven for 24 hours. The weight of the hybrid composite samples were taken by using electronic scale.

Thus,

$$\textit{Moisture Content (\%)} = \frac{M_1 - M_0}{M_0} \times 100 \qquad \textbf{(Equation 3.1)}$$

where,

M_0 is the mass of PALF/KF sample before heated in the oven

M_1 is the mass of PALF/KF sample after heated in oven

3.3.2 Determination of Water Absorption

Equation 3.2 shows evaluation of percentage of water absorption of PALF/KF hybrid composite. There were 3 types of samples which are neat polymer, untreated fibre and treated fibre composite. Five samples of each treatment were cut into 10mm (length) x 10mm (width) x 3mm (thickness) for the evaluation of water absorption according to ASTM D570. The average of percentage of water absorption was calculated. Before being immersed in distilled water for every 2 hours consecutively until 24 hours at room temperature, the samples were weighed as M_0. Then, the samples were then weighed again by using electronic scale as M_1 after every 2 hours of immersion. **Figure 3.10** shows the samples for the test. Thus:

$$\textit{Water Absorption (\%)} = \frac{M_1 - M_0}{M_0} \times 100 \qquad \textbf{(Equation 3.2)}$$

where,

M_0 is the mass of PALF/KF sample before immersed in distilled water

M_1 is the mass of PALF/KF sample after immersed in distilled water

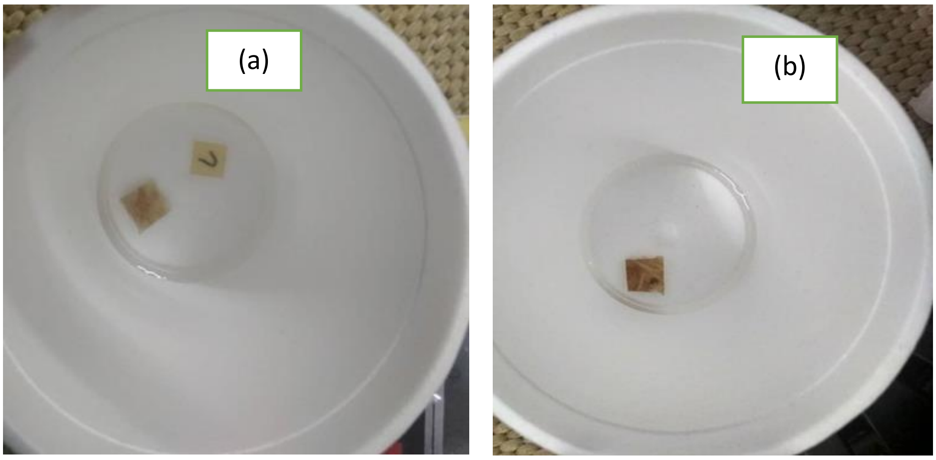

Figure 3.10: (a)Neat polymer and untreated fibre composite; (b)Treated fibre composite.

3.3.3 Determination of Density

Electronic densimeter was used to evaluate the density of PALF/KF composite. 10mm x 10mm x 3mm size of PALF/KF samples for each composition were cut according to ASTM D792. After that, the mass of the samples were weighed and denoted as (m) before immersed into the water. The amount of water before and after immersed of the sample was labelled as volume (V) and these two parameters were used to identify the density of PALF/KF samples as shown in **Equation 3.3**. **Figure 3.11** below shows electronic densimeter used in the test. **Figure 3.12** shows the samples after the test.

Figure 3.11 : Electronic densimeter.

$\rho = m/V$ **(Equation 3.3)**

where,

ρ is the density of PALF/KF hybrid composite

m is the mass of PALF/KF hybrid composite

V is the volume of water

Figure 3.12 : Neat fibre after density test.

3.3.4 Tensile Properties of PALF/KF Hybrid Composite

Tensile test is used to identify the mechanical properties of the materials which also recognized as a simple and common test. Tensile stress, tensile strain, maximum elongation, yield stress and Young Modulus are the properties that can be obtained from tensile test in term of mechanical. Instron 8872, Universal Testing Machine as in **Figure 3.12** was used for this study. Tensile test was done according to ASTM D3039 that stands for Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials.

Figure 3.13 : Instron 8872 Machine.

There were at least fifteen samples tested as there are 5 samples from neat polymer, treated fibre composites and untreated fibre composites. Pneumatic holder will held the samples vertically and to indicate that fracture occur within line drawn, the samples were marked at the centre. The sample was applied with load until rupture occurred and Bluehill 3 Software was use to record the values of tensile strength. While conducting the test, 1mm/min of load speed was applied. Dimension of 150mm (l) x 15mm (w) x 3mm (t) were set for the samples to be tested. By considering the cross-sectional area, the failure area of the fibres were determined by **Equation 3.4** as follows in below:

$A = \pi r^2$ **(Equation 3.4)**

where,

A is the area of the sample

r is radius of the sample

3.3.5 Flexural Properties of PALF/KF Hybrid Composite

ASTM D790 standard was used for the flexural tests performed by using a three-point bending setup. For this flexural method, five samples were at least tested for each types of samples. 100mm (l) x 10mm (w) x 3mm (t) were dimension of the samples which will be tested by using Instron 5585, a Universal Testing Machine and the result obtained were recorded in Bluehill 3 Software as shown in **Figure 3.13**. 1mm/min was the load speed applied for this test.

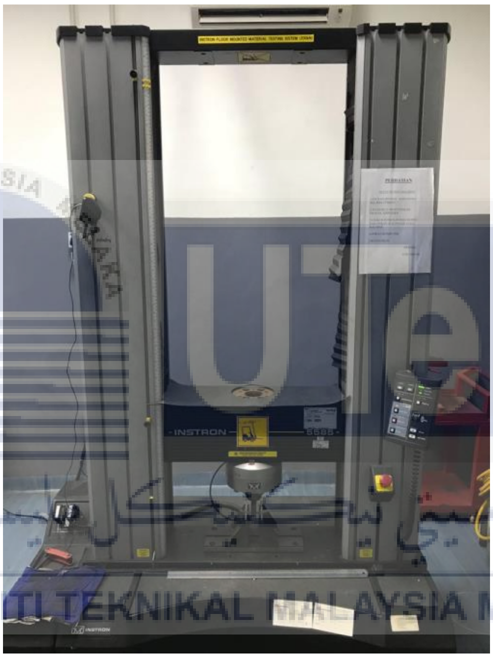

Figure 3.14 : Instron 5585 Machine.

By using this expression, flexural strength and flexural modulus were then obtained:

$\sigma_f = 3PL / 2bd^2$ **(Equation 3.5)**

$E_f = L3m / 4bd^2$ **(Equation 3.6)**

where,

L is the support span

b is the width of the sample

d is the thickness

P is maximum load

m is the slope of initial straight line portion of the load-displacement curve

3.3.6 Morphological Test

A scanning electron microscope (SEM) was used to performed morphological studies in detail on the fractured surface of tensile test samples at an accelerating voltage of 10kV. Besides, the surface of the fracture area can be referred to the surface of the tensile test failure samples. Conductive layer of metal which consist of electron microscopy would coated limited or non-conductive material sample to enable and enhance the sample imaging resolutions. Thus, to provide electrical conductivity without significantly affect the resolution and obtaining good quality results, the samples were coated in platinum. **Figure 3.14** (a), (b) and (c) below show sample coating machine, sample placement and SEM respectively, used for microstructure analysis.

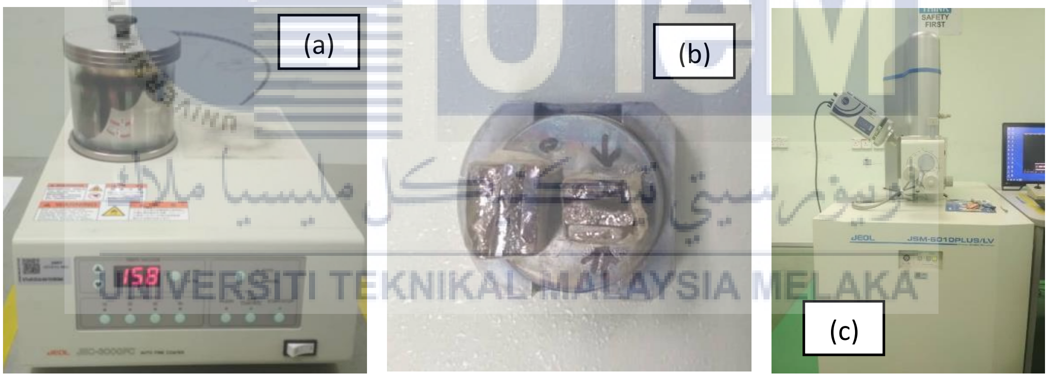

Figure 3.15 (a), (b) and (c) : Sample Coating Machine, Sample Placement, and Scanning Electron Microscope.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter covered results and discussions of the project. Physical, mechanical and morphological properties will be discussed thoroughly in this chapter.

4.1 The Effect of Chemical Treatment on the Physical Properties of Pineapple Leaf Fibre / Kenaf Fibre Reinforced Vinyl Ester Hybrid Composites

4.1.1 Moisture Content

Quantity of water contained in a material can be defined as moisture content. There were 5 samples from each treatment where the average value would be determined. **Table 4.1** below shows the value of moisture content.

Table 4.1: Moisture content of PALF/KF reinforced VE hybrid composite.

Sample	**Moisture Content**
Neat Polymer	0%
Untreated Fibre Composite	6%
Treated Fibre Composite	2%

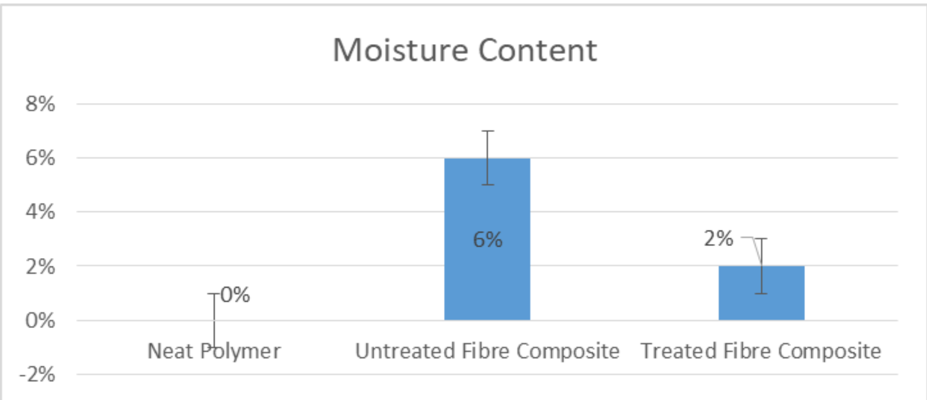

Figure 4.1 : Moisture content of PALF/KF reinforced VE hybrid composite.

Based on the results obtained in **Figure 4.1**, moisture content increased when there is presence of fibre. There is no changes for polymer samples. This might be due to characteristics of polymer which is hydrophobic. Hydrophobic is non-polar molecule that repelled from the water molecules. Moisture content for treated fibre composite decreased dramatically at 2% compared to untreated fibre composite which is 6%. This behavior is desirable since natural fibre is hydrophilic in nature. Hydrophilic is polar molecules that attracted to water molecules. Moisture content was reduced due to the surface treatment done on the composite (Faruk *et al.*, 2012). Based on the literature, alkalization removed lignin and hemicellulose that improve mechanical properties.

4.1.2 Water Absorption

Fifteen sample were prepared for this testing. Each parameter have 5 sample and the average results will be recorded. Water absorption is the amount of water absorbed under specified qualifications. Water absorption influenced by a few factors. The factors were fibre content, fibre orientation, temperature, area of exposed surface, void content and hydrophilicity of individual components (Akil *et al.*, 2011). The data obtained from the experiment were recorded in the **table 4.2**.

Table 4.2: Water absorption of PALF/KF reinforced VE hybrid composite.

Sample	Water Absorption
Neat Polymer	29%
Untreated Fibre Composite	42%
Treated Fibre Composite	34%

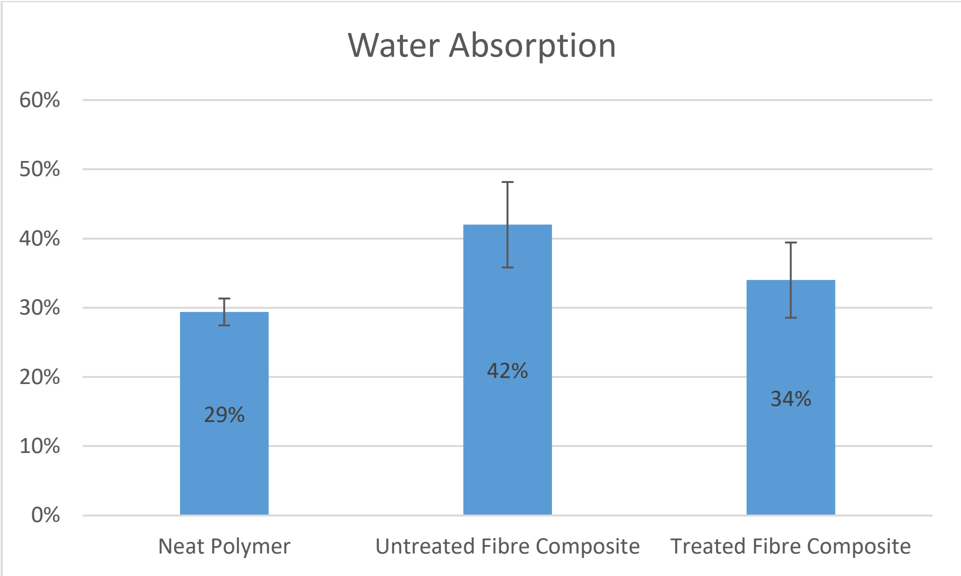

Figure 4.2: Water absorption of PALF/KF reinforced VE hybrid composite.

From the obtained results, it can be seen that neat polymer had the lowest intake of water absorption at 29%. The presence of fibre increases water absorption. Untreated fibre composite had the most water absorption for 42% compared to treated fibre composite for 34%. As untreated fibre composite had wax and oil in the surface, the water absorption was higher compared to treated fibre composite which had remove the contaminant. The result is in good agreement with a previous study that state water absorption reduced significantly by fibre treatment (Faruk *et al.*, 2012). Hydroxyl group attracted water molecules by chemical interaction called chemical bonding when natural fibre was exposed to humidity environment. Poor adhesion between fibre and matrix interaction surface was because of resin which is hydrophobic and compatible with natural fibre which is hydrophilic.

4.1.3 Density

Natural fibre has their own density where density can be defined as a measurement that differentiate the amount of matter of an object to its volume. The result calculated from the experiment states that treated fibre composite had the lowest density at 0.944 g/cm^3 compared to neat polymer at 1.114 g/cm^3 and untreated fibre composite at 1.087 g/cm^3. This is because alkaline treatment promote better mechanical properties as impurities such as wax and oil were removed completely without damaging surface of fibre. It was a limitation to the increase in mechanical strength as adhesion between fibre and composite matrix was weak (Oliveira et al., 2017).

Table 4.3 : Density of PALF/KF hybrid composite.

Sample	Density
Neat Polymer	1.114
Untreated Fibre Composite	1.087
Treated Fibre Composite	0.944

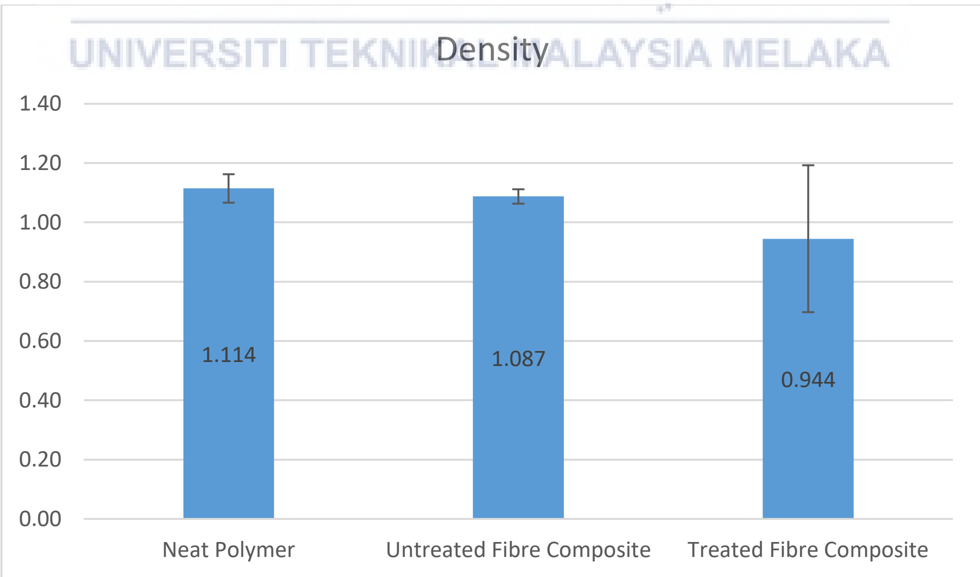

Figure 4.3: Density of PALF/KF reinforced VE hybrid composite

4.2 The Effect of Chemical Treatment to the Mechanical Properties of PALF/KF Reinforced Vinyl Ester Hybrid Composites

4.2.1 Tensile Test

Tensile test were performed in this project to determine the mechanical properties of PALF/KF reinforced vinyl ester hybrid composites. Tensile strength and Young's Modulus were investigated in the tensile test. Tension load was applied and the specimens were being pulled apart is the procedure of tensile test. The ultimate tensile strength was used to evaluate the fibre resistance towards maximum force and stress while being stretched before rupture. Furthermore, Young's Modulus will measured stiffness of elastic materials and become a quantity used to classify materials. Fifteen samples were prepared according to the ASTM D3039. Each parameter have 5 samples and the average results will be recorded. **Figure 4.4** shows failure of tensile test on neat polymer. **Table 4.4** shows data obtained on tensile test.

Figure 4.4: Tensile test on neat polymer

Table 4.4: Tensile strength of PALF/KF reinforced VE hybrid composite

Sample	Tensile Strength (MPa)
Neat Polymer	17.54
Untreated Fibre Composite	4.92
Treated Fibre Composite	7.80

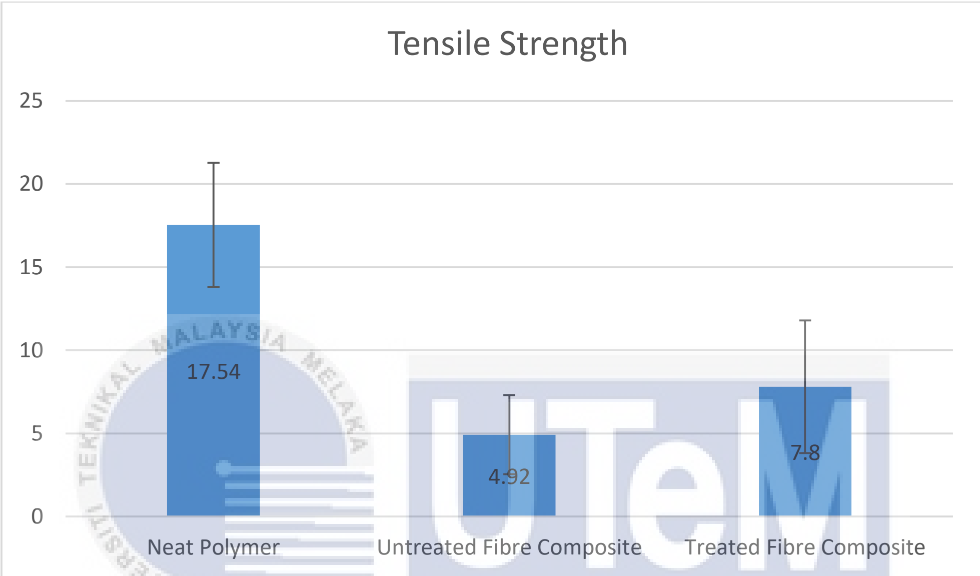

Figure 4.5: Tensile strength of PALF/KF reinforced VE hybrid composite

5 wt% of fibre was used as reinforcement material to study the effect of treatments on mechanical and adhesion properties of the composite. Neat polymer shows the highest tensile strength at 17.54MPa. The presence of fibre decreases the tensile strength of the fibre composite. The effect of NaOH treatment was portrayed on the tensile properties of PALF/KF reinforced VE hybrid composite. The result shows that treated fibre composite had more tensile strength at 7.80MPa compared to untreated fibre composite at 4.92MPa. The result was supported by previous research that states the strength and interfacial adhesion increase by chemical treatment (Mohd Nurazzi, Khalina, Sapuan, Dayang Laila, 2017).

4.2.2 Flexural Test

Flexural test is performed to evaluate strength and ability of the material to hold off deformation under loading before breaking point happens. The test was operated to figure out value of modulus elasticity in bending. Flexural modulus is known as the ability to withstand bending deformation. **Figure 4.6** and **Figure 4.7** below shows the sample after performing flexural test.

Figure 4.6: Flexural test on neat polymer

Figure 4.7: Flexural test on untreated fibre composite

Three point bending test was conducted in this project. Three point bending test is simple to conduct in term of specimen preparation and testing. Flexural stress and flexural modulus are the parameters obtained from the result. Figure shows the results acquired after performing flexural test. The flexural strength on the treated fibre composite was the highest at 72.40MPa compared to untreated fibre composite at 13.12MPa and neat polymer at 46.78MPa. It shows that alkaline treatment improve mechanical properties. This can be supported by previous researcher that states sodium hydroxide solution increased mechanical properties of the fibre composite compared to untreated fibre composite (Saba, Paridah and Jawaid, 2015). **Table 4.5** shows data obtained on flexural test.

Table 4.5: Flexural strength of PALF/KF reinforced VE hybrid composite

Sample	Flexural Strength (MPa)
Neat Polymer	46.78
Untreated Fibre Composite	13.12
Treated Fibre Composite	72.40

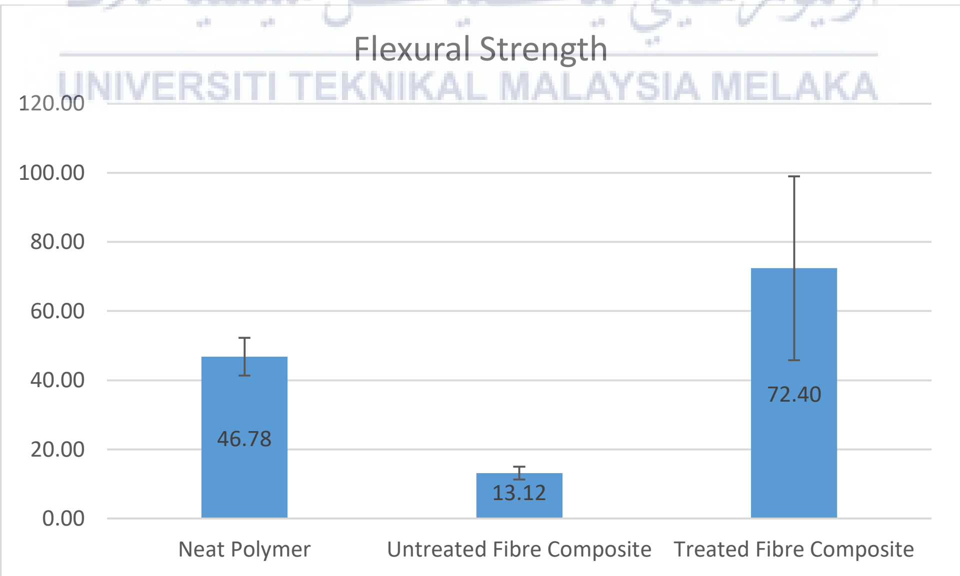

Figure 4.8: Flexural strength of PALF/KF reinforced VE hybrid composite

4.3 Morphological Analysis

Morphological analysis was conducted on the fracture surface of tensile test sample. SEM on the fracture surface of tensile test for neat polymer and pineapple leaf fibre/ kenaf fibre hybrid composite was conducted to analyze the behavior of the samples. There was a significance difference between neat polymer and composite samples. Neat polymer surface fracture in **Figure 4.9** shows a smooth surface (Nadlene Razali, S. M. Sapuan, Mohammad Jawaid, 2016). Surface fracture of untreated are shown in **Figure 4.10**. It can be observed that there are fibre pull-out. The surface of the untreated fibre was rough. It was shown in the figure that the distribution of the fibre and matrix were not uniform.

Finally, **Figure 4.11** shows treated fibre composite. There are presence of void, air bubble, matrix and less fibre pull-out in treated PALF/KF hybrid composite. The distribution between fibre content and matrix was uniform compared to untreated fibre. In NaOH treatment, the surface of the fibre was relatively smoother compared to untreated fibre (Threepopnatkul, Kaerkitcha and Athipongarporn, 2009). Between fibre and matrix, the interfacial bonding was slightly stronger which led to higher flexural properties.

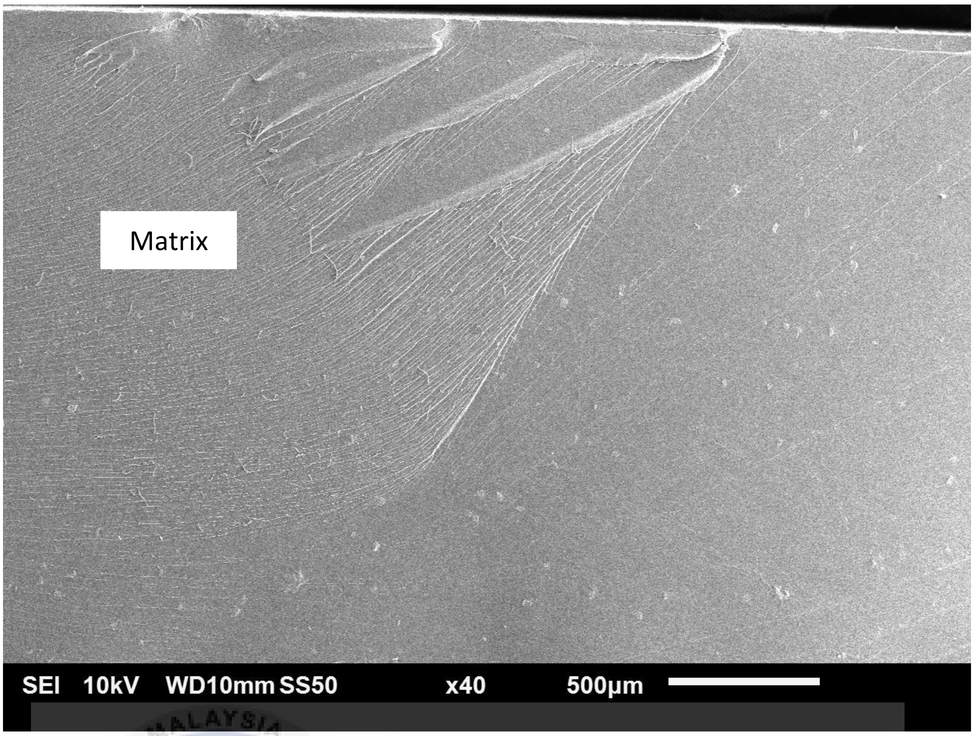

Figure 4.9: SEM micrographs of neat fibre

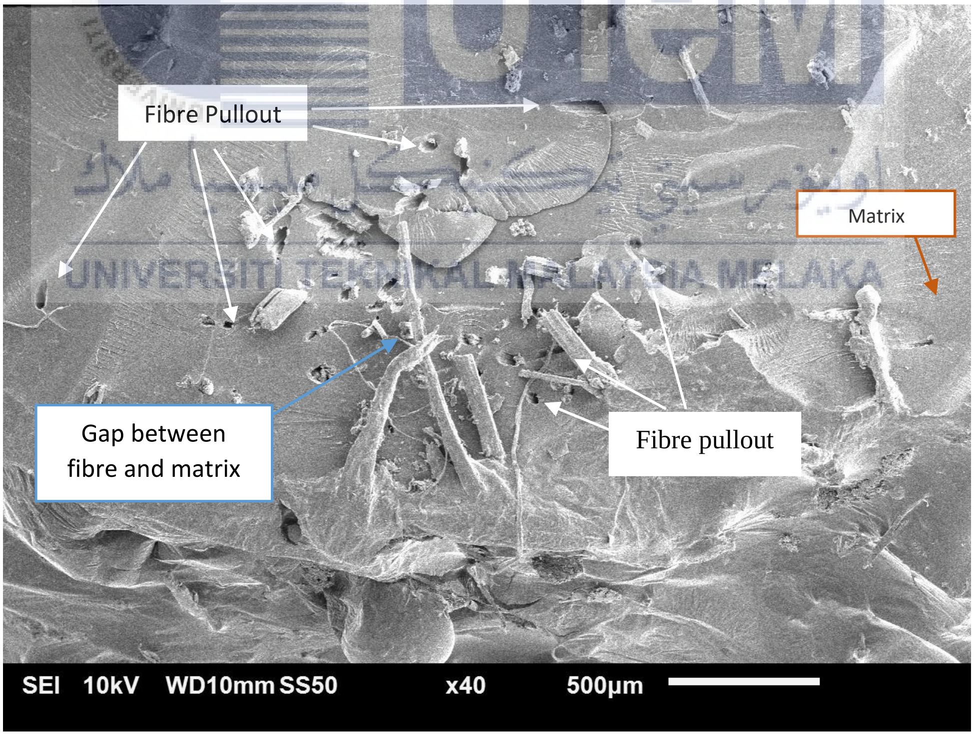

Figure 4.10: SEM micrograph of untreated PALF/KF hybrid composite

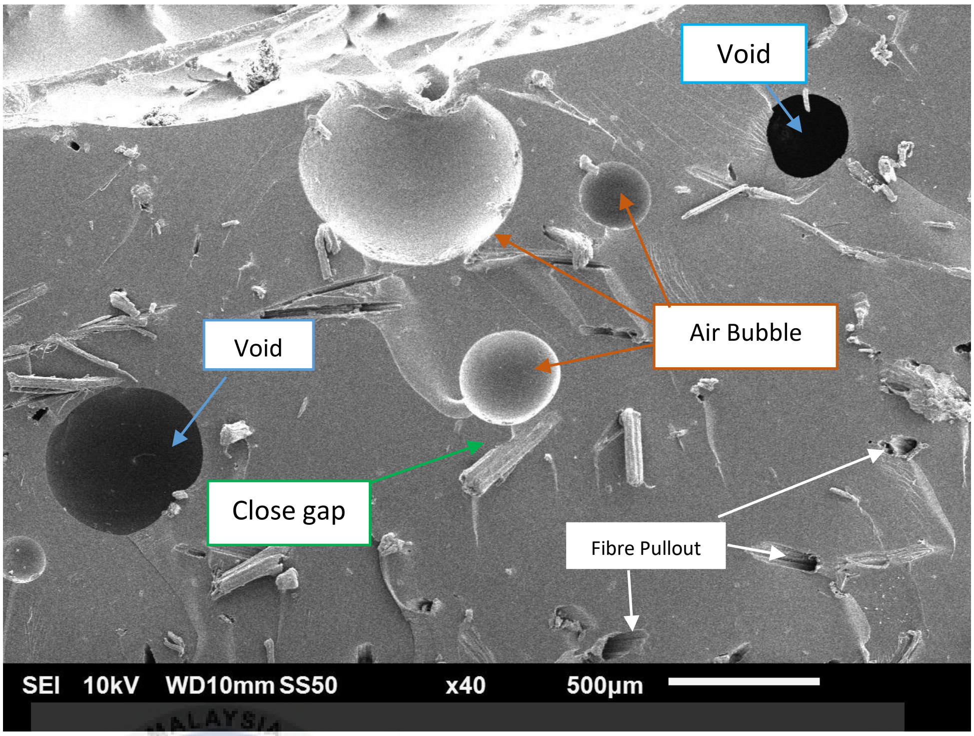

Figure 4.11: SEM micrograph of treated PALF/KF hybrid composite

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The mechanical and physical properties of pineapple leaf /kenaf fibre reinforced vinyl ester hybrid composites were analyzed. Hybrid composites can be defined as adding two types of material into one single material. Hybrid composite was used as one type of fibre would complement the other fibre lacking. Alkaline treatment was performed to remove lignin and hemicellulose of the fibre. This treatment could promote better mechanical properties such as tensile strength and flexural strength.

Based on the results, treated fibre composite had more tensile strength compared to untreated fibre composite while neat polymer shows the highest tensile strength. In flexural test, the flexural strength on the treated fibre composite was the highest compared to untreated fibre composite and neat polymer.

For physical properties, the result of moisture content show no changes for neat polymer sample. The moisture content on treated fibre composite decreased compared to untreated fibre composite. In water absorption, treated fibre composite shows lowest intake of water compared to untreated fibre composite. This is because alkaline treatment reduced water absorption. Poor adhesion between fibre and matrix interaction surface was because resin is hydrophobic while natural fibre is hydrophilic in nature. The density of the treated fibre composite also decrease compared to untreated fibre composite while neat polymer shows the highest density. The results of the mechanical properties can be supported by SEM results which shows matrix and fibre pull-out in the fracture samples. In conclusion, the mechanical and physical properties of pineapple leaf / kenaf fibre reinforced vinyl ester hybrid composite shows positive improvement by having alkaline treatment.

As for future work recommendation, a need for review and improvement of the test have to be done. My recommendation is study on different fibre loading of pineapple leaf / kenaf fibre reinforced vinyl ester hybrid composite. The other is study on different surface treatment of pineapple leaf / kenaf fibre reinforced vinyl ester hybrid composite.

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