STUDY OF EFFECT NATURAL WEATHERING ON HYBRID KENAF BAST / GLASS FIBRE FILLED UNSATURATED POLYESTER COMPOSITE

By

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LIST OF ABBREVIATIONS

CO_2	Carbon dioxide
GF	Glass fibers
KF	Kenaf fiber
SEM	Scanning electron microscope
TGA	Thermogravimetric analysis
DTG	Derivatives thermogravimetric
DSC	Differential scanning calorimetry analysis
MEKP	Methyl ethyl ketone peroxide
UP	Unsaturated polyester
cm	Centimeter
MPa	Mega pascal
m	Meter
Tg	Glass transition temperature

Kajian Kesan Cuaca terhadap Komposit Hibrid Kenaf bast/Gentian Kaca Terisi Poliester Tak Tepu

ABSTRAK

Di dalam kajian ini, komposit kenaf dan komposit hibrid kenaf/gentian kaca telah disediakan dengan menggunakan proses sapuan tangan. Kesan cuaca terhadap sifat-sifat mekanikal, morfologi dan haba komposit kenaf dan komposit hibrid kenaf/gentian kaca telah dikaji. Kekuatan tensil komposit hibrid kenaf/gentian kaca diperolehi pada 130 MPa dan modulus tensil pada 3030 MPa sebelum didedahkan pada cuaca. Malangnya, modulus tensil kedua-dua jenis bahan tersebut mula berkurangan selepas bulan pertama pendedahan cuaca melalui tempoh pendedahan cuaca dengan pengurangan modulus tensil yang berterusan. Walau bagaimanapun, dengan perbezaan penurunan di antara komposit kenaf dan komposit kenaf diperkuatkan gentian kaca ini menunjukkan bahawa gentian kaca boleh menjadi penguat yang baik untuk komposit berprestasi tinggi. Daripada keputusan kekuatan lenturan yang diperolehi dapat dilihat dengan jelas bahawa gentian asli dan kompositnya tidak dapat bertahan dengan keadaan persekitaran kerana ia mempunyai sifat kebolehbasahan yang lemah, ketidakserasian dengan beberapa polimer matriks dan penyerapan lembapan yang tinggi. Oleh kerana sifat-sifat penyerapan kelembapan yang tinggi, terdapat pembentukan kekosongan di dalam komposit yang boleh mengurangkan sifat-sifat mekanikal komposit seperti kekuatan lenturan dan modulus lenturan yang jelas disokong oleh SEM. Bagaimanapun beberapa pengubahsuaian boleh dilakukan kearah meningkatkan sifat-sifat mekanikal dan ia adalah cukup baik untuk mencapai komposit berprestasi tinggi dengan formulasi sistem yang betul semasa proses pengubahsuaian dan sifat-sifat haba hibrid kenaf sama-sama terjejas oleh cuaca, untuk kedua-dua kenaf dan gentian hibrid kenaf-kaca sebelum pendedahan, komposit menunjukkan penurunan berat awal yang perlahan dan berterusan sehingga penurunan berat yang ketara dikesan pada kira-kira suhu 390^{0}C. Semakin pendedahan cuaca meningkat, penurunan berat bermula serendah 290^{0}C. Ini adalah disebabkan oleh penyerapan kelembapan yang membawa kepada interaksi antara muka.

Study of Effect Natural Weathering on Hybrid Kenaf Bast/Glass Fiber Filled Unsaturated Polyester Composite

ABSTRACT

In this research, pure kenaf composite and kenaf/glass fiber hybrid composite was prepared by using hand lay-up process. The effect of weather on mechanical, morphology and thermal properties of pure kenaf composite and kenaf/glass fiber hybrid composites were studied. Tensile strength of kenaf / glass fiber hybrid composite was found to be at 130 MPa and tensile modulus was at 3030 MPa before weathering. Unfortunately, tensile modulus of both materials starts to decrease after the first weathering month through to the weathering periods with constant reduction of tensile modulus. However, the different of reduction between pure kenaf composite and glass fiber reinforced kenaf composite indicates that, glass fiber can be a good reinforcement candidate for high performance composites. From the flexural strength result obtained, it is clearly seen that natural fiber and their composites are not able to with stand environmental condition because they have poor wettability, incompatibility with some polymeric matrices and high moisture absorption. Due to the high moisture absorption properties, there are formations of void in the composites which can reduce the mechanical properties of composite such as flexural strength or flexural modulus which is clearly supported by SEM results. For both pure kenaf composites and hyprid kenaf/glass fiber composites before exposure to natural weathering show slow and steady initial weight loss until major weight loss at 390 °C The exposure to weathering the weight loss process started at 290 °C. This is due to photo-oxidation and thermo-oxidation which lead to surface oxidation, chain scission and breakdown of the tie molecules.

CHAPTER 1

INTRODUCTION

1.1 Overview

Kenaf fiber is unique and potentially reliable natural material that occupied the mind scientist engineered. The development of high-performance engineering products made from natural resources is increasing worldwide, due to renewable and environmental issues. Among the many different types of natural resources, kenaf plants have been extensively exploited over the past few years. Kenaf fiber is extracted from bast fiber of kenaf plants and properties of kenaf fiber composite are comparable to conventional fiber composites. Moreover, kenaf fiber composite can be produced using conventional fiber composite manufacturing and kenaf fiber composite have a bright future due to its renewability and eco-friendly. Hence this work is presenting reinforces of resin composite with kenaf fiber.

1.2 Background

The quest to develop high-performance materials made from natural resources is increasing worldwide, especially the material with integrity to be used in much application. The greatest challenge in working with natural fiber reinforced plastic composites is their large variation in properties and characteristics with respect to different condition (Omar et al, 2012). Bio composite's properties are influenced by a number of variables, including the fiber type, environmental conditions (where the plant fibers are sourced), processing methods, and any modification of the fiber. Recently there has been a surge of interest in the industrial applications of composites containing bio fibers reinforced with biopolymers (Bras et al, 2010).

In the other hand, there is a growing trend to use bio fibers as fillers and/or reinforces in plastics composites. This is due to their flexibility during processing, highly specific stiffness, and low cost (on a volumetric basis) makes them attractive to manufacturers.

However, using kenaf constitute also give some disadvantage which occur during the addition of natural fibers, including kenaf fiber into a polymer matrix. The lack of good interfacial adhesion between the two components, which results in poor properties in the final product.

Kenaf fibers, as reinforcement, have recently attracted the attention of researchers because of their advantages over other established materials. They are environmental friendly, fully biodegradable, abundantly available, renewable, cheap and have low density. Plant fibers are light weight compared to glass, carbon and aramid fibers. The biodegradability of plant fibers can contribute to a healthy ecosystem while their low cost and high performance fulfills the economic interest of industry. When natural fiber-reinforced plastics are subjected, at the end of their life cycle, to combustion process or landfill, the released amount of CO_2 of the fibers is neutral with respect to the assimilated amount during their growth. The abrasive nature of fiber is much lower which leads to advantages in regard to technical process and recycling process of the composite materials in general. Natural fiber-reinforced plastics are the most environmental friendly materials, which can be composed at the end of their life cycle. Natural fiber composites are used in place of glass mostly in non-structural applications. A number of automotive components previously made with glass fiber composites are now being manufactured using environmentally friendly composites.

Glass fibers (GF) are the most common reinforcement for polymeric matrix composites. Their principal advantages are the relationship between their low cost, high tensile strength, high chemical resistance, and insulating properties. The disadvantages are low tensile modulus, relatively high specific gravity, sensitivity to abrasion during handling, low fatigue resistance, and high hardness. The compositional difference and low manufacturing cost make it more attractive materials.

1.3 Problem Statement

The best way to increase the material efficiency without sacrificing environmental safety is to employ natural fiber reinforced composite materials. Producing the material with the focus on improvement aspects is very important in various applications. The goals are to increase the performance of the materials and also to find the solution to reduce the cost. The latest incorporation natural material develops plastic based material has resulted in higher material properties and more possibilities use in many different applications.

The natural fiber-reinforced composites is growing rapidly due to their mechanical properties, processing advantages and low density. The availability of natural fibers such as kenaf in Asia is more and also has some advantages over traditional reinforcement materials in terms of density, renewability, recyclability, abrasiveness and biodegradability. However, natural fiber has low resistance to environmental and ability to absorb moisture from the atmosphere in large quantities because cellulose is hydroscopic and most polymeric fibers swell due to moisture absorption.

This absorption of moisture leads to alterations in weight, dimensional, strength and stiffness. In addition, plant fiber is exposed to biological decay and it is weaken with age and exposure to light. Plant fibers are not as durable as synthetic polymeric fibers. So in this study, we will incorporate fiber glass into kenaf unsaturated polyester composite to reduce the effect of weathering on kenaf fiber.

1.4 Objectives

1. To study the effect of glass fiber addition into kenaf unsaturated polyester composite on mechanical properties.
2. To study the effect of weathering on mechanical properties of pure kenaf unsaturated polyester composite and kenaf / glass fiber hybrid unsaturated polyester composite.
3. To characterize surface morphology and thermal stability of pure kenaf unsaturated polyester composite and kenaf / glass fiber hybrid fiber unsaturated polyester composite.

1.5 Scopes

The main scope of this research is to fabricate kenaf / glass fiber hybrid composites and pure kenaf composites to understand the effect of weather on these composites and effect of glass fiber addition into kenaf unsaturated polyester compositres by examining mechanical, surface morphology and thermal properties. The test will be conducted based on standard ASTM D3039 for tensile test , D7264 for flexural test and finally, the thermal properties will be also studied by using thermogravimetric analyzer (TGA), Differential Scanning Calorimetry (DSC) Analysis and Scanning electron microscope (SEM) to observation degradation occur in natural fiber and development micro cracking mechanism in matrix and to assist increasing roughness of the surface .

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Polymer Reinforcement

The researchers across the globe have begun to focus attention on increasing demand for environmentally friendly materials (Tan et al., 2011). Besides ecological considerations natural fibers exhibit many advantageous properties which promote the replacement of synthetic fibers in polymer composites, offer high potential for an outstanding reinforcement in lightweight structures (Aji et al., 2009). Natural fibers are derived from a renewable resource and do not require a large energy requirement to process and biodegradable. These fibers also offer significant cost advantages and therefore the utilization of lightweight, lower cost natural fibers such as jute, flax, hemp, sisal, abaca, coir offer the potential to replace a large segment of the synthetic fibers in numerous applications (Yuhazri et al., 2012).

In recent years this natural fiber composites have been used in many engineering applications due to natural properties that they offer such a variety of lightweight, reform, cheap and environmentally friendly. Natural fiber composites are used in various industries such as automotive, sporting goods, marine, electrical, construction and household appliances (Wallenberg& Weston, 2004). Kenaf, sisal, coir, banana, hemp, pulp, wood flour, palm oil, pineapple leaf and coir is the main natural fiber used as reinforcement (Rowell et al., 1997).

Kenaf fiber provides the hardness and strength values are high. They also have a higher aspect ratio which makes them suitable for use as reinforcement in polymer composites (Sanadi et al., 1995). Kenaf (Hibiscus cannabinus, family *Malvaceae L.*) is a perennial plant herb. Kenaf is a plant heat-season annual lane. The attractive feature of kenaf fiber is inexpensive, lightweight, Reform, biodegradability and certain properties of high mechanical. Kenaf contains bast fiber containing 75% cellulose and 15% lignin and offers the advantage of being environmentally friendly and safe environment (Mansur & Aziz, 1983). Kenaf fibers have superior flexural strength and excellent tensile strength that makes the kenaf good candidate for many applications (Aji et al., 2009). However, it has several drawbacks, including high moisture absorption, which have a negative impact on the mechanical properties (Coutinho et al., 1997; Rowell et al., 1999).

Incompatibility between the fibers hydrophilic and hydrophobic thermoplastic and thermoset matrices require proper maintenance to improve the adhesion between the fiber and the matrix (Gassan&Cutowski, 2000; Dhakal et al., 2007). Natural weather is usually performed to determine the resistance of materials under natural conditions (Stark & Matuana, 2006). The idea is to determine how far in biodegradability was possessed by the officer when exposed to natural weather. Sunlight, rain and dew is part of natural weather together. Ultraviolet (UV) rays from the sun have been reported as a major cause of failure when the weather is a natural polymer article (Schier, 2000). Notes, yellow, cracking, brittleness and loss of transparency is a common observation that encountered with conventional polymers exposed to natural weather (Schier, 2000). Unsaturated polyester has been popularly used as a thermoset polymer matrix composite (Aziz et al., 2005; Aziz & Ansell., 2004).

2.2 Fiber

A single fiber of all plant based natural fibers such as kenaf consists of several cells. These cells are formed out of crystalline micro fibrils based on cellulose, which are connected to a complete layer, by amorphous lignin and hemi cellulose. This structure is a good example of a composite with lignin hemi cellulose matrix and cellulose fiber reinforcement (P. Methacanon, et al., 2010). Strength is supplied by highly crystalline cellulose whereas ductility is supplied by amorphous lignin and other components. The cell wall consists of hollow tube with four different layers in one primary and three secondary cell walls stick together in a multiple layer composite. These cell walls differ in composition and in the orientation (spiral angle) of the cellulose micro fibers. The spiral angle of the fibrils and the content of cellulose determine mechanical properties of cellulose based natural fibers (M. John and S. Thomas., 2008).

Due to the relatively high cost of synthetic fibers and health concern, it becomes necessary to use natural based fiber as a viable alternative. Fiber is better than other organic non fiber in terms of spin ability and tensile strength (Amal &Eman, 2013). It is blended with other fiber like cotton making it very suitable for making fabric and or polymer composite. It is used for making yarn, fabric and garments. In the recent time, the demand for fibers is increasing and especially fiber extracted from the bast due to higher quantity of cellulose and the fiber being long which lead to better entanglement.

Interface refers to the boundary between two phases, namely fiber and matrix. Bonding between fiber and matrix accomplished through the interface with different bonding mechanisms (Suhailah et al., 2012). The fiber or filler interfacial adhesion plays an important role in determining the mechanical properties of a polymer composite. A better interfacial bond will improved properties such as inter laminar shear strength, fatigue and corrosion resistance (P. Methacanon, et al., 2010). The figure 2.1 shows the schematic illustration of natural plant cell walls.

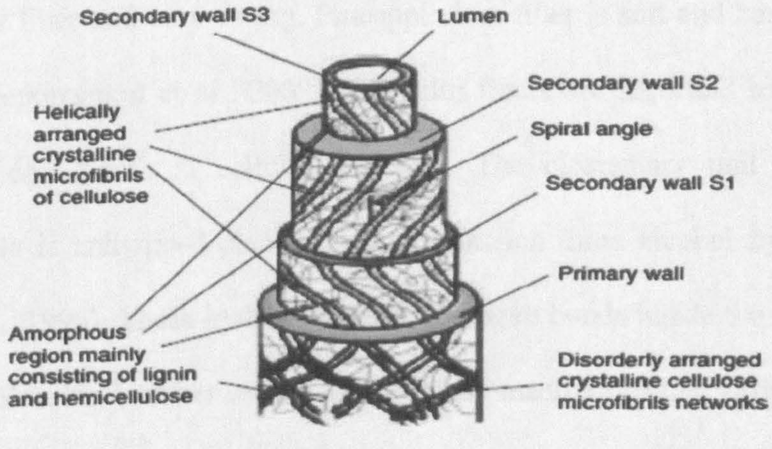

Figure 2.1: Schematic picture of cell wall of the natural plants.

2.2.1 Natural Fibers

Natural fibers are subdivided based on their origins i.e., whether they are derived from plants, animals, or minerals and natural fibers are renewable resources in many developing countries of the world; they are cheaper, pose no health hazards and, finally, provide a solution to environmental pollution by finding new uses for waste materials. Furthermore, natural fiber reinforced polymer composites form a new class of materials which seem to have good potential in the future as a substitute for scarce wood and wood based materials in structural applications.

Fibers obtained from the various parts of the plants are known as vegetable fibers. These fibers are classified into three categories depending on the part of the plant from which they are extracted. 1. Bast or Stem fibers (jute, mesta, banana etc.) 2. Leaf fibers (sisal, pineapple, screw pine etc.) 3. Fruit fibers (cotton, coir, oil palm etc.) Many of the plant fibers such as coir, sisal, jute, banana, palmyra, pineapple, talipot, hemp, etc. find applications as a resource for industrial materials (Arun et al., 2010).

The properties of plant fibers depend mainly on the nature of the plant, locality in which it is grown, age of the plant, and the extraction method used. For example, coir is a hard and tough multicellular fiber with a central portion called "lacuna". Sisal is an important leaf fiber and very strong. Pineapple leaf fiber is soft and has high cellulose content (Threepopnatkul et al., 2009). Oil palm fibers are hard and tough, and show similarity to coir fibers in cellular structure. The elementary unit of a cellulose macromolecule is anhydro-d-glucose, which contains three alcohol hydroxyls (-OH) (Bledzki et al., 1996). These hydroxyls form hydrogen bonds inside the macromolecule itself (intramolecular) and between other cellulose macromolecules (intermolecular) as well as with hydroxyl groups from the air.

Therefore, all plant fibers are of a hydrophilic nature; their moisture content reaches 8-13% (Mohamed et al., 1995). In addition to cellulose, plant fibers contain different natural substances. The most important of them is lignin. The distinct cells of hard plant fibers are bonded together by lignin, acting as a cementing material.

The lignin content of plant fibers influences its structure, properties and morphology. An important characteristic of vegetable fiber is their degree of polymerization (DP). The cellulose molecules of each fiber differ in their DP and consequently, the fiber is a complex mixture of polymer homologue $(C_6H_{10}O_5)_n$. Bast fibers commonly show the highest DP among all the plant fibers (~10,000). Traditionally these fibers have been used for making twines, ropes, cords, as packaging material in sacks and gunny bags, as carpet-backing and more recently, as a geotextile material (Threepopnatkul et al., 2009).

2.2.2 Properties and Characteristics of Natural Fibers

Natural fibers that is sensitive towards mixing and forming equipment, which can contribute to significant reducing equipment maintenance costs. They also present safer handling and working conditions compared to synthetic reinforcements, such as fiberglass. Processing them is the environment friendly, offer better working conditions and, therefore, reduction the risk of skin or respiratory problems. The most interesting of the natural fiber is a positive environmental impact of them. Natural fibers are a renewable resource, where they biodegradable and their production require little energy. One major drawback of natural compared to synthetic fibers, is the achievement of uniformity, multi-dimensional, and their mechanical properties (even between individual natural fibers in the same planting).

Therefore, the main task to be solved, in order to increase acceptance of natural fibers as a quality alternative to conventional reinforcing fiber, is to develop high-performance natural fiber reinforced composite. Natural fiber generally contains many hydroxyl groups, which make them polar and hydrophilic in nature (Zou et al., 2010).

2.2.3 Effect of Weather Conditions on Natural Fiber Based Composite

Effect of weather conditions on natural fiber based composite is a major problem that hinders the quest of new composite materials because almost all polymer composites absorb moisture in humid atmosphere. The effect of absorption of moisture leads to the degradation of fiber matrix interfacial region creating poor stress transfer efficiencies resulting in a reduction of mechanical and dimensional properties.

One of the main concerns for the use of natural fiber reinforced composite materials is their susceptibility to weather conditions which effect on physical mechanical, and thermal properties. Therefore, this problem should be addressed in order that natural fiber may be considered as a viable reinforcement in composite materials.

Several studies in the use of natural fiber reinforced polymeric composites have shown that the sensitivity of certain mechanical and thermal properties to moisture uptake can be reduced by the use of coupling agents and fiber surface treatments

(Prachayawarakorn et al., 2010). Water molecules diffusion in polymeric composites has shown to be governed by three different mechanisms. The first involves of diffusion of water molecules inside the micro gaps between polymer chains. The second involves capillary transport into the gaps and flaws at the interfaces between fiber and the matrix. This is a result of poor wetting and impregnation during the initial manufacturing stage. The third involves transport of micro cracks in the matrix arising from the swelling of fibers (Zou et al., 2010).

Generally, based on these mechanisms, diffusion behavior of polymeric composites can further be classified according to the relative mobility of the penetrant and of the polymer segments, which is related to either Fickian, non-Fickian or anomalous, and an intermediate behavior between Fickian and non-Fickian (Arun et al., 2010). In general moisture diffusion in a composite depends on factors such as volume fraction of fiber, voids, viscosity of matrix, humidity and temperature. Thus, in this study, the influence of both fiber reinforcement and effect of moisture environment (weathering) will be studied.

2.2.4 Reinforcement of Composites with Glass Fiber

Glass fiber has insulation properties, chemical resistance, ultraviolet resistant, high thermal stability and high tensile strength. These properties will enhance the property when it incorporates in composites (Kasama and Nitinat, 2009). Around 1990s, development in natural fiber composites is emerging as realistic alternatives to glass-reinforced composites in many different applications to name a few: in building materials, Biomedical, pharmacy etc. (Joshi et al., 2004). Natural fiber composites such as kenaf based, hemp fiber-epoxy, flax fiber-polypropylene (PP), and china reed fiber-PP are particularly attractive in automotive applications because of lower cost and lower density (Joshi et al., 2004). Glass fibers used for composites have density of 2.5 g/cm3 and cost between RM 7.5and RM 9.00/kg. In comparison, kenaffibers cost between RM 0.9 and RM 4.00/kg (Joshi et al., 2004).

While, natural fibers traditionally have been used to fill and reinforce thermosets, natural fiber reinforced thermoplastics, especially polypropylene composites, have attracted greater attention due to their added advantage of recyclability (Joshi et al., 2004). Table 2.1 shows the typical values for various properties of cured polyester unfilled and reinforced. Natural fiber composites are also claimed to offer environmental advantages such as reduced dependence on non-renewable energy/material sources, lower pollutant emissions, lower greenhouse gas emissions, enhanced energy recovery, and end of life biodegradability of components. Since, such superior environmental performance is an important driver of increased future use of natural fiber composites, a thorough comprehensive analysis of the relative environmental impacts of natural fiber composites and conventional composites, covering the entire life cycle, is warranted.

Table 2.1: Typical values for various properties of cured polyester unfilled and reinforced.

	Unfilled casting	Glass fiber chopped strand laminate (hand lay-up)	Glass woven cloth laminate (hand lay –up)	Glass roving rod (extruded)
Specific gravity	12	16	17	19
Tensile strength (lb/in^2)	9000	20000	50000	120000
Flexural strength (lb/in^2)	18000	30000	60000	150000
Compressive strength (lb/in^2)	20000	20000	35000	70000
Impact strength (lb/in^2)	2	20	25	70
Glass constant (%weight)	0	30	55	70

2.2.5 Properties of Natural Filler in Polymer Composite

Natural fiber shows comparatively poor fiber/matrix interactions, water resistance, and relatively lower durability. The weaker interfacial or adhesion bonds between highly hydrophilic natural fibers and hydrophobic, non-polar organophilic polymer matrix, leads to considerable decrease in the properties of the composites and, thus, significantly obstructs their industrial utilization and production. However, several approaches and schemes have been established to supplement this deficiency in compatibility, including the introduction of coupling agents and/or various surface modification techniques. The surface of the natural fibers can be modified and this can be achieved by physical, mechanical, and/or chemical means. For any composite, the circumstances for substantial reinforcement and virtuous properties are the homogeneous distribution of the reinforcing component, orientation,