The Effect of Layer Number on Mechanical Properties and Dimensional Stability of Hybrid Kenaf-Glass Fiber Unsaturated Polyester Composite.

by

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LIST OF ABBREVIATIONS

cm	centimeter
˚C/min	degree Celsius per minutes
CO_2	carbon dioxide
F	glass fiber composites
Ft	feet
FK	kenaf- glass fiber hybrid composite (two layer)
FFK	kenaf- glass fiber (dominant) hybrid composite (three layer)
FFKK	kenaf- glass fiber hybrid composite (four layer)
GPa	giga Pascal
g/cm^3	gram per centimeter cubic
K	kenaf composites
Kg	kilogram
KKF	kenaf (dominant) - glass fiber hybrid composite (three layer)
MAH	maleic anhydride
MAPP	maleic anhydride-polypropylene
MJ	mega Joule
MPa	mega Pascal
MEKP	methyl ethyl ketone peroxide
m	meter
mm	millimeter
µm	micrometer
NaOH	sodium hydroxide
N/m^2	newton per meter square
PMC	polymer matrix composites
PBZX	polybenzoxazine

PLLA	poly-L-lactic acid
UD	Unidirectional
vol. %	volume percent

KESAN BILANGAN LAPISAN TERHADAP SIFAT MEKANIK DAN KESTABILAN DIMENSI KOMPOSIT HIBRID KENAF-GENTIAN KACA POLIESTER TIDAK TEPU

ABSTRAK

Komposit hibrid kenaf-gentian kaca poliester tidak tepu disediakan menggunakan kaedah pelapisan tangan. Kenaf yang digunakan adalah dalam bentuk gentian tikar. Kesan bilangan lapisan ke atas sifat sifat mekanik dan kestabilan dimensi terhadap komposit hibrid kenaf-gentian kaca poliester tidak tepu telah dikaji. Kesan bilangan lapisan di dalam komposit hibrid kenaf-gentian kaca poliester tidak tepu menunjukkan lekatan antara muka yang baik di antara matrik dan gentian sekaligus meningkatkan kekuatan tensil dan lenturan komposit hibrid kenaf-gentian kaca poliester tidak tepu. Keputusan kekuatan tensil dan kekuatan lenturan menunjukkan empat lapis komposit hibrid kenaf-gentian kaca poliester tidak tepu mempunyai kekuatan tensil tertinggi iaitu 52.665 MPa manakala kekuatan lenturan tertinggi adalah pada dua lapis komposit iaitu 92.77 MPa. Tiga lapis komposit hibrid kenaf-gentian kaca poliester tidak tepu menunjukkan kestabilan terhadap suhu tertinggi iaitu 452.34 ˚C dengan nisbah gentian kaca kepada kenaf adalah 2:1. Kestabilan dimensi tertinggi apabila direndam dalam larutan ethanol selama 1800 minit dengan kadar perubahan sebanyak 2 peratus juga adalah menggunakan sampel dua lapis komposit hibrid kenaf-gentian kaca poliester tidak tepu.

THE EFFECT OF LAYER NUMBER ON MECHANICAL PROPERTIES AND DIMENSIONAL STABILITY OF HYBRID KENAF-GLASS FIBER UNSATURATED POLYESTER COMPOSITE

ABSTRACT

Hybrid kenaf-glass fiber unsaturated polyester composite was prepared by hand lay-up technique. The kenaf was used in a fiber mat form. The effect of layer number of hybrid kenaf-glass fiber unsaturated polyester composite on mechanical properties and dimensional stability were studied. The effect of layer number of hybrid kenaf-glass fiber unsaturated polyester composite has shown good interfacial adhesion between matrix and fiber reinforced composite thus, increasing the tensile and flexural strength of hybrid kenaf-glass fiber unsaturated polyester composite. Results show that four layer of hybrid kenaf-glass fiber unsaturated polyester composite laminates have the highest tensile strength i.e. 52.665 MPa while highest flexural strength was obtained in two layer of hybrid kenaf-glass fiber unsaturated polyester composite laminate i.e. 92.77 MPa. Three layer of hybrid kenaf-glass fiber unsaturated polyester composite laminate have showed the highest thermal stability at high temperature 452.34˚C with ratio glass fiber to kenaf 2:1. Highest dimensional stability in ethanol solution for 1800 minutes with average of 2 % changes was shown in two layer of hybrid kenaf-glass fiber polyester composite laminate.

CHAPTER 1

INTRODUCTION

1.1 Background

In the course of nature life, composite materials were subjected to both mechanical loading and exposed to severe environmental conditions. The natural fiber reinforced composite are reasonably strong, lightweight and free from health hazard, and hence it`s have the potential to be used as material for strong components such as like building materials, shipping, automotive and etc. despite the advantages listed above, they suffer from some limitations such as poor moisture resistance especially water absorption and low strength compared to synthetic fiber such as glass as argued by Hazizan et al. (2009).

Research by Mohanty & Misra (2000) explained as industry attempts to lessen the dependence on petroleum based fuels and products there is an increasing need to investigate more environmental friendly, sustainable materials to replace the existing glass fiber and carbon fiber reinforced materials. Therefore, attention has recently shifted to the fabrication and properties of natural fiber reinforced material. Natural fibers develop an option for most widely applied synthetic fiber in composites technology. The interest in natural fiber was known because it is cheap and lighter which provides better stiffness per weight than glass. Natural fiber source is renewable where it is considered being green and environmental friendly. The fact that it causes less impact on the environment is proven since natural fiber can be recycled thermally.

Therefore, according to Norlin et al. (2010) stated that the usages of the natural fibers were retained in all sorts of applications. The natural fiber that was used in this study was kenaf fiber. Kenaf exhibits good mechanical properties, low density, non- abrasiveness during processing, high specific mechanical properties and biodegradability. It can be used as a domestic supply of cordage fiber in manufacture of rope, twine carpet backing and burlap. According to Mohanty & Misra (2000), these fibers are abundant, cheap, renewable, and easily recycled. Other advantages include low density, high toughness, comparable specific strength properties, reduction in tool wear, ease of separation, decrease energy of fabrication, and CO_2 neutrality.

Kenaf is one of the natural (plant) fiber used as reinforcement in polymer matrix composite (PMCs). Kenaf or its scientific name (*hibiscus cannabinus,L. family maleavea*) has been found by Karnani et al. (1997) to be an important source of fiber for composites, and other industrial applications. Kenaf is well known as a cellulosic source with both economic and ecological advantages; in 3 months (after sowing the seeds), it is able to grow under a width range of weather conditions, to height of more than 3m a based diameter of 3-5cm. This statement is supported by previous studies by Aziz et al. (2005), which mention that growing speed may reach 10 cm/day under optimum ambient conditions. From the viewpoint of energy consumption by Nishino (2004), it takes 15MJ of energy to produce 1kg of kenaf, whereas it takes 54MJ to produce 1kg of glass fiber.

According to Nordin et. al. (2010), kenaf requires less water to grow because kenaf fiber has growing cycle to 150 to 180 days with average yield of 1700kg/ha. Most Asians countries are surrounded by areas with high humidity. Based on this fact, the effect of humidity on composite materials should be investigated by the researchers to ensure the composite materials can be used in humid environment safely. Historically, all types of polymer composites were absorbed moisture when immersed in water on in humid environment.

The natural fiber composites are also able to absorb moisture. It is because of the hydrophilic nature of the fiber that is very sensitive towards water absorption, causing instability in the properties. Research`s by Kim & Seo (2006) find that the moisture penetrates into the microgaps between polymer chains of composites material. The other common mechanisms are capillary transport into the gaps and flaws at the interfaces between fibers and polymer, because of incomplete wettability and impregnation; and transport by micro cracks (formed during compounding process) in the matrix.

In this study, kenaf/unsaturated polyester resin was added with glass fiber as hybrid composite to improve mechanical and dimensional stability. The effect of lamination, water absorption, thickness swelling behavior of kenaf composites and kenaf-glass fiber hybrid composites were investigated. The effect of lamination on flexural properties of kenaf-glass fiber hybrid composites was investigated.

1.2 Problem statement

Unsaturated polyester was used as matrix resin along with fiber reinforcement and hybrid with glass fiber to form a composite. Glass fiber has excellent stiffness and good mechanical properties. However, glass fiber can cause problem in term of renewability and high in cost. Alternatively, natural fiber offers the advantages of being inexpensive, biodegradable, moderate stiffness, and environmentally safe. Therefore, kenaf fibers were used as alternative to reduce the percentage usage of glass fiber. The performance and properties of fiber-reinforced hybrid composites was modified according to the needs of applications. Thus, in this study, the layer number and sequence of lamination was manipulated to investigate the performance in mechanical properties and dimensional stability of the composite product produced.

1.3 Objectives

The overall aim of this study is to assess the effect of lamination on hybrid kenaf-glass fiber unsaturated polyester composites. The principal objectives of this study were as follows:

i. To study the effect of layer number of kenaf and glass fiber on mechanical properties of hybrid kenaf-glass fiber unsaturated polyester composites.
ii. To analyze the dimensional stability of hybrid kenaf-glass fiber unsaturated polyester composites in water, ethanol and methanol.
iii. To determine the thermal degradation temperature of hybrid kenaf-glass fiber unsaturated polyester composites.

1.4 Scope of study

The main principal of the study is to investigate the effect of lamination on properties of hybrid kenaf-glass fiber unsaturated polyester composites such as tensile properties, flexural properties, swelling behavior, thermal degradation and dimensional stability in water, ethanol and methanol. There are two stages for the study, the first stage emphasize on the hand lay-up processes of the materials into testing specimen whereas the second stage focus more on the experimental testing such as tensile testing, flexural testing, dimensional stability test, and thermogravimetry analysis. The hybrid composites were precisely cut and weighed before carefully hand lay-up to obtain lamination without air entrapped. The samples were cut according to standard ASTM3039 for tensile test, ASTM D790 for flexural test, ASTM D5229 for water absorption test. Finally, the selected testing was performed and the results were analyzed. The tensile testing was done to investigate tensile strength, elongation at break and tensile modulus. The flexural testing was performed to investigate flexural strength and flexural modulus of hybrid kenaf-glass fiber unsaturated polyester composites. Then the samples were immersed into water, ethanol, and methanol separately to investigate the dimensional stability of hybrid kenaf-glass fiber unsaturated polyester composite.

CHAPTER 2

LITERATURE REVIEW

2.1 Polymer Composites

2.1.1 Introduction of Polymer Composites

According to Mallick et. al. (1990), polymer composite are materials made by combining a polymer with other types of materials, such as fiber and filler. In general, the intention of making polymer composites is to have low weight, high performance materials that are superior in a number of ways to the individual components. A variety of fiber can be used in polymer composites; carbon and glass are the most commonly used man-made fibers meanwhile hemp, flex and kenaf are examples of natural fibers.

Aznizam et al. (2000) claimed that polymer composites are combinations of two materials in which one of the materials called the reinforcing phase is in the form of fiber sheets or particles and are embedded in the other material called the matrix phase. The primary functions of the matrix are to transfer stresses between the reinforcing fibers or particles and to protect them from mechanical and environmental damage whereas the presence of fibers or particles in a composite improves its mechanical properties such as strength, stiffness.

In addition, research by Czvikovszky & Nagy (2000) showed a composite is therefore a synergistic combination of two or more micro constituents that differ in physical form and chemical composition and which are insoluble in each other. The objective is to take advantage of the superior properties of both materials without compromising on the weakness of either. Composite materials have successfully substituted the traditional materials in several light weight and high strength applications.

Barone & Schmidt (2005) argued that the reasons why composites are selected for such applications are mainly their high strength to weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness. Typically, in a composite, the reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated correctly it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material .

The strength of the composites depends primarily on the amount, arrangement and type of fiber or particle reinforcement in the resin. Supported by Czvikovszky (2000) research, the additional reason for fiber reinforcement is to increase the specific area of adhesion, which is a determinant factor influencing the composite properties. The most important criteria of reinforced materials is the good adhesion between matrix and reinforcement, the larger the specific area of connection the better is the adhesion. The first geometry is when the diameter is very small in comparison to the length; this is the geometry of fiber.

The second cases are large diameters with small thicknesses, i.e. flakes, disk-shaped geometries. The reinforcing effect in given directions can be achieved with the fiber type reinforcements. In practice the length over diameter (l/d) ratio (shape factor) has importance to discriminate short and long fiber composites. If l/d >50, the composite is long fiber reinforced, if the fiber length is smaller than the critical fiber length we call it short fiber composite. Critical fiber length is the fiber length when tensile load causes fiber fracture in a composite. Smaller fibers slip out from the matrix material without fracture.

2.2 Natural fiber reinforced composites.

Lignin is phenol propane based amorphous solidified resin, filling the spaces between the polysaccharides fibers, like concrete. Hemicelluloses form much shorter branched chain consisting of five and six carbon ring sugar. Cellulose is often found as a relative high modulus, fibrillar component of many naturally occurring composites. According to John & Thomas (2008), cellulose is resistance to strong alkali (17.5wt %) but is easily hydrolyzed by acid to water-soluble sugars. Cellulose is relatively resistance to oxidizing.

Second component is hemicellulose. Hemicellulose differs from cellulose in three aspects. Firstly, they contain several different sugar units such as xylose, mannose and galactose whereas cellulose contains only 1, 4-β-D-glucopyranose units. Secondly, they exhibit a considerable degree of chain branching containing pendant side groups giving rise to its non-crystalline nature, whereas cellulose is a linear polymer. Thirdly, the degree of polymerization of native cellulose is 10-100 times higher than that of