Faculty of Mechanical Engineering

A STUDY ON MECHANICAL PROPERTIES OF HYBRID KENAF/KEVLAR FIBRE REINFORCED THERMOPLASTIC COMPOSITES

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A STUDY ON MECHANICAL PROPERTIES OF HYBRID KENAF/KEVLAR FIBRE REINFORCED THERMOPLASTIC COMPOSITES

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DECLARATION

I declare that this project report entitled "A study on mechanical properties of hybrid kenaf/Kevlar fibre reinforced thermoplastic composites" is the result of my own work except cited in the references.

Signature : …………………………

Name : NG CHER SEAN

Date : …………………………

SUPERVISOR'S APPROVAL

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

Signature : ………………………………………………………………………

Name : ASSOC. PROF. DR. SIVAKUMAR A/L DHAR MALINGAM

Date : ………………………………………………………………

ABSTRACT

Nowadays, many applications focus on the cost and the performance of the materials. A material which can be recycled and reused is preferable compared to other. A hybrid composite which consists of two or more different fibres in a single matrix has become an interesting topic in the field of fibre reinforced composite. In this project, the woven kenaf fibre and Kevlar fibre along with thermoplastic matrix polypropylene were used to fabricate hybrid composites. Different stacking sequence of composite laminates structures were introduced, which include kenaf/kenaf/kenaf [K/K/K], kenaf/Kevlar/kenaf [K/KV/K], Kevlar/kenaf/Kevlar [KV/K/KV] and Kevlar/Kevlar/Kevlar [KV/KV/KV]. Tensile, quasi-static indentation and low-velocity impact tests were carried out to investigate the effect of fibre configurations on the mechanical and indentation properties of hybrid kenaf/Kevlar fibre reinforced polypropylene composites. The ultimate tensile strength of [KV/K/KV] was found to be higher than [K/KV/K] by 71% whereas Young's Modulus of [KV/K/KV] was also higher than [K/KV/K] by 41%. Quasi-static indentation test was conducted and the result showed that [KV/KV/KV] can withstand the highest load followed by [KV/K/KV], [K/KV/K] and lastly [K/K/K]. Moreover, the low-velocity impact test was carried out using Instron drop tower impact system. The specimens were tested at different impact energy levels. The result showed the non-hybrid kenaf composites were weak against impact while hybridizing the kenaf fibre with Kevlar fibre, the result was significantly different.

ABSTRAK

Pada masa kini, banyak aplikasi memberi tumpuan kepada kos dan prestasi bahan. Bahan yang boleh dikitar semula dan digunakan semula adalah lebih baik berbanding dengan yang lain. Komposit hibrid yang terdiri daripada dua atau lebih jenis serat yang berbeza dalam matriks tunggal telah menjadi topik yang menarik dalam bidang komposits serat. Dalam projek ini, gentian kenaf tenunan dan serat Kevlar bersama dengan termoplastik matriks polipropilena digunakan untuk mengarang komposit hibrid. Susunan filem struktur laminat komposit yang berbeza telah diperkenalkan, iaitu kenaf / kenaf / kenaf [K / K / K], kenaf / Kevlar / kenaf [K / KV / K], Kevlar / kenaf / Kevlar [KV / K / KV] dan Kevlar / Kevlar / Kevlar [KV / KV / KV]. Ujian lekapan tegangan quasi statik dan kesan impak rendah dijalankan untuk menyiasat kesan konfigurasi serat pada sifat mekanikal dan lekukan komposit polipropilena bertetulang kenaf / Kevlar hibrid. Kekuatan tegangan muktamad [KV / K / KV] didapati lebih tinggi daripada [K / KV / K] sebanyak 71% manakala Young's Modulus [KV / K / KV] juga lebih tinggi daripada [K / KV / K] oleh 41%. Ujian lekukan quasi statik dijalankan dan hasilnya menunjukkan bahawa [KV / KV / KV] dapat menahan beban tertinggi diikuti oleh [KV / K / KV], [K / KV / K] dan terakhir [K / K / K]. Selain itu, ujian impak rendah dilakukan menggunakan sistem impak menara drop Instron. Spesimen telah diuji pada tahap tenaga yang berbeza. Hasilnya menunjukkan komposit kenaf bukan hibrid adalah lemah terhadap impak sementara hibridkan serat kenaf dengan serat Kevlar, hasilnya jauh berbeza.

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LIST OF ABBREVIATIONS

FRP	Fibre-Reinforced Polymer
ASTM	American Society for Testing and Materials
QSI	Quasi-Static Indentation
LVI	Low-Velocity Impact
PEEK	Polyetheretherketone
PP	Polypropylene
PPS	Polyphenylene Sulphide
AHP	Analytical Hierarchy Process
HDPE	High-Density Polyethene
K	Kenaf
KV	Kevlar
UTM	Universal Testing Machine
SEM	Scanning Electron Microscopy

LIST OF SYMBOL

ρ_c - Density of composite

ρ_m - Density of matrix material

V_m - Volume fraction of matrix material

ρ_f - Density of fibre material

V_f - Volume fraction of fibres.

E_L - Longitudinal modulus of the composite

E_f - Modulus of the fibres

E_m - Modulus of the matrix

E_T - Transverse modulus of the composite

v - Poisson's ratio of composite

v_f - Poisson's ratio of fibre material

v_m - Poisson's ratio of matrix material

σ_c - Ultimate strength of composite

σ_f - Ultimate strength of the fibre

σ_m - Ultimate strength of material

w - Weight

w_{kenaf} - Weight of kenaf fibre

w_{Kevlar} - Weight of Kevlar fibre

w_{pp} - Weight of polypropylene

ρ_{kenaf} - Density of kenaf fibre

ρ_{Kevlar} - Density of Kevlar fibre

ρ_{pp} - Density of polypropylene

V_v - Void volume fraction

ρ_{ct} - Theoretical density of composite

ρ_{cm} - Measured density of composite

CHAPTER 1

INTRODUCTION

1.1 Background

A composite is a material made from two or more constituents with different physical or chemical properties. After combined the materials, it will produce a material with different properties from the individual components. The characteristics of composites are lightweight, high strength, high stiffness and easily mouldable to complex shapes (Mallick, 2008). Hybrid composite is known as a composite with two or more fibres with different properties embedded in a single matrix (Cheung et al. 2009).

Fibre-Reinforced Polymer (FRP) is a composite material that consists of natural or synthetic fibres embedded in polymer matrices. Nowadays, engineering fields such as automotive and aerospace use FRP in the applications of drive shaft, windmill blades and support beams. The characteristics of FRP which are high stiffness and strength, lightweight, high durability and easy to be shaped made it widely used in the engineering fields. (Senguttuvan & Lillymercy, 2015).

In general, there are two types of fibres, which are natural fibres and synthetic fibres. The characteristics of natural fibres are low manufacturing cost, lightweight and low density compared to synthetic fibres. However, synthetic fibres provide higher strength and stiffness compared to natural fibres (Puglia et al. 2008).

Thermoplastic composite materials are becoming more popular in many applications. The reason of thermoplastics become an alternative choice in fabrication compared to thermosets are the capabilities and manufacturing benefits (Farag, 2008). Furthermore, there are many pros and cons between thermoplastics and thermosets. The advantages of thermoplastics are recyclable, easy to repair by welding and high toughness while the disadvantages are poor melt flow and require a specific temperature to melt during fabrication. In contrast, the advantages of thermoset are low resin viscosity, good thermal stability and chemically resistant whereas the disadvantages are non-recyclable and non-post formable (Kabir et al., 2012).

In this study, mechanical properties and indentation properties of hybrid kenaf/Kevlar fibre reinforced composites are investigated to explore the potential of using hybrid composites in engineering applications.

1.2 Problem statement

Nowadays, many applications focus and concern on the cost and the performance of the materials. A material which can be recycled and reused is preferable compared to other since the concept of 3R – Reduce, Reuse and Recycle is getting more and more important in daily life. Hybridizing fibres in thermoplastic composites can provide better mechanical properties and natural executions. To further understand the thermoplastic-based hybrid composites, it is important to study their mechanical and indentation properties.

1.3 Objectives

The objectives of this project are as follows:

1. To investigate the effect of fibre configurations on the mechanical and indentation properties of hybrid kenaf/Kevlar fibre reinforced polypropylene composites.
2. To analyse the morphological damage of hybrid kenaf/Kevlar fibre reinforced polypropylene composites.

1.4 Scope of project

The scope of the project is focused on only 3 layers fibre configurations of hybrid kenaf/Kevlar fibre reinforced polypropylene composites. The layup configurations of composites must be symmetrical due to the different coefficient thermal expansion of fibres. Throughout this project, thermoplastic polypropylene is used as the matrix because it is recyclable and can be shaped easily compared to thermoset. Besides that, kenaf fibre is chosen due to easily available in market while Kevlar fibre is chosen because of its amazing impact resistivity.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review provides information, findings and studies of previous researchers on a particular topic. Detail and information related to this project such as properties of composite, type of fibre and mechanical properties of the hybrid composites used will be discussed. Previous researcher's works are required to enhance the understanding of this topic.

2.2 Composite

The composite is defined in micromechanics as a heterogeneous body, consisting of reinforcing elements such as fibres, particles, or crystals embedded in a matrix material. Besides that, the term 'composite' includes a variant of materials such as concrete, semi-crystalline polymers, paper, leather, bone and so on. Another significant aspect of composites is they are normally fabricated by a lamination process in which the layers are oriented in a predetermined way. Moreover, there are two main types of fibre-reinforced composites called continuous fibre and short (chopped) fibre composites. Aligning all the fibres or weaving a cloth and injection the resulting structure with a matrix material can create a continuous fibre- reinforced composites (Sendeckyj, 2016).

Composite materials are very useful in industrial aerospace, marine and recreational structures application. Basically, there are some advantages and disadvantages of composite materials. The advantages are weight reduction around 20% -50%, high impact resistance, high damage tolerance to increase accident survivability and the mechanical properties can be tailored by 'lay-up' pattern. In contrast, the disadvantages of the composite materials are higher material cost, non-visible impact damage within the composites, maintenance is different from those of metal structures. The composite materials are better than metals in term of strength-to-weight ratio, sometimes up to 20% performance (Maria, 2013).

The term 'Fibre-Reinforced Polymer' (FRP) refers to a composite which comprises fibres and a polymer matrix material. For the sake of convenience, one of the terms will be referred to as the matrix, while the others as the reinforcement. Figure 2.1 shows the composition of composite. The matrix is the continuous phase of the composite. Its function is to provide the shape to the structure. The matrix component encounters whatever forces might be imposed. The main function of the reinforcement is to provide strength, stiffness and other mechanical properties to the composites (Strong, 2008).

FRP possess low density, high stiffness and high strength characteristics. These properties make FRP become one of the best methods to enhance the structural efficiency in design of aerospace vehicles and other industrial applications (Soykok, 2013).

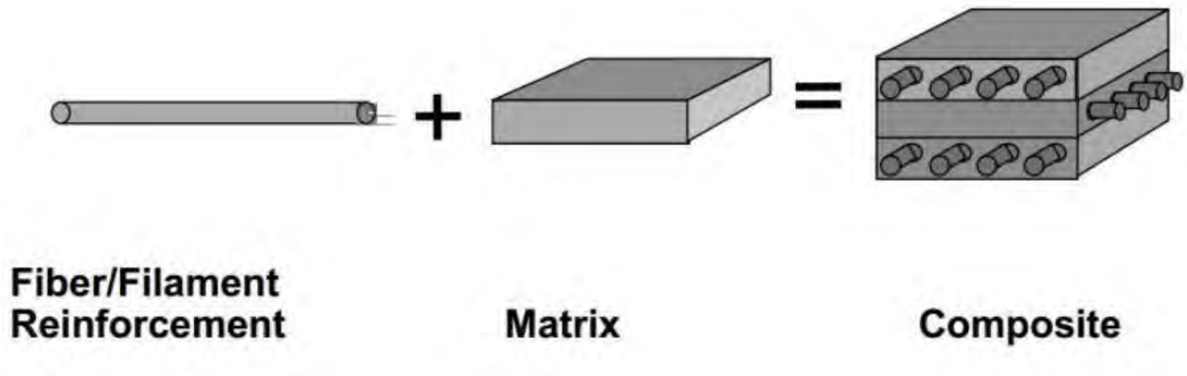

Figure 2.1: Composition of composite (Maria, 2013)

2.2.1 Matrix

Matrix material is a polymer that composed of molecules made of many simpler and tiny units called monomer. For the fibres to carry maximum load, the matrix needs to have a lower modulus and better elongation than those of fibres. Basically, the matrix material plays an important role in FRP composite. The significant functions of matrix materials are binding the fibres together and fixing them in the desired geometrical arrangement, transferring the load to fibres by adhesion or friction, providing rigidity and shape to the structural member as well as acting as a protection to the fibres against chemical, mechanical damages and impact (Potyrala, 2011).

Important characteristics that need to be considered in selecting a matrix are stiffness, strength, fracture toughness, thermal and electrical conductivity. From the manufacturing perspective, one important factor that needs to be considered in the selection of a matrix for an FRP application is the expansion of the fibre and matrix during the processing (Hensher, 2016).

Resins are the primary component of a matrix. The resins can be categorized into two types, thermoplastic and thermosetting polymers. Thermoplastic polymers are ductile in nature compared to thermoset polymers. The molecules do not cross-link, thus thermoplastics are flexible and can be easily reformed and reshaped by heating. Several examples of thermoplastics are nylon, polyetheretherketone (PEEK), polypropylene (PP), and polyphenylene sulphide (PPS). On the other hand, thermoset polymers usually exhibit high brittleness, high rigidity and high chemical resistance. The drawbacks of thermoset polymers are they cannot be recycled and reformed. Polyester resin material is one of the thermosetting examples which is having excellent bonding characteristics. The special of polyester for FRP are low viscosity, fast cure time and dimension stability. Furthermore, another example of thermoset is epoxy resin. Epoxy resin is known for their excellent strength and creeps resistance, good adhesion to fibres, chemical and solvent resistance, good electrical properties, high glass transition temperature, low shrinkage and volatile emission during cure.

As discussed above, the thermoplastic resins offer several benefits over thermoset resins when used as matrix materials for FRP. These advantages are cost and performance-related. Cost savings can be achieved in term of infinite shelf-life of thermoplastic at room temperature. The significant performance of thermoplastic over thermoset are improved toughness and increase of temperature stability. For instance, the fracture toughness of thermoplastic resins and their composites may be 10 times than thermoset resins. Some processing temperatures for thermoplastics can be as high as 300˚C. Some properties of several FRP matrix material are shown in Table 2.1 (Benin et al. 2015).

Table 2.1: Properties of several FRP matrix material (Benin et al. 2015).

	Polyester	BMI	Polyimide	Epoxy	PEEK
Tensile Strength (MPa)	20-100	40-100	40-190	55-130	103
Tensile Modulus (GPa)	2.1-4.1	2.7-4.2	3-5	2.5-4.1	1.1
Ultimate Strain (%)	1-6	1.2-6.6	1-60	1-8	30-150
Density (g/cm^3)	1-1.45	1.2	1.3-1.4	1.1-1.3	1.3
T_g (˚C)	100-140	220-320	210-340	50-260	144
CTE (µm/m/˚C)	55-100	21-73	14-50	45-90	55

2.3 Fibre

The term 'fibre' means a material made into a long filament with diameter up to 15µm. In the dictionary, the definition of fibre is a thread or filament from which a vegetable tissue, mineral substance, or textile is formed. In general, greater diameters increase the probability of surface defects. For continuous fibres, the aspect ratio of length and diameter can range from thousand to infinity. Besides that, the main purposes of fibres are to carry the load and provide stiffness, strength and other structural properties to the FRP. The fibres in FRP need to have the characteristics of high ultimate strength, high modulus of elasticity, low variation of strength among fibres, high stability of their strength during handling and high uniformity of diameter and surface dimension among fibres. Generally, the fibre can be classified into two groups that are natural fibres and synthetic fibres (Tuakta, 2005). Table