DEVELOPMENT AND ANALYSIS OF NEW INTRAPLY FOR GLASS FIBER AND KENAF FIBER IN COMPOSITE STRUCTURE APPLICATIONS

LOH YEN CHING
B051110129

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT AND ANALYSIS OF NEW INTRAPLY FOR GLASS FIBER AND KENAF FIBER IN COMPOSITE STRUCTURE APPLICATIONS

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

by

LOH YEN CHING
B051110129
911110-05-5350

FACULTY OF MANUFACTURING ENGINEERING
2015

DECLARATION

I hereby, declared this report entitled 'Development and Analysis of New Intraply for Glass Fiber and Kenaf Fiber in Composite Structure Applications' is the results of my own research except as cited in references.

Signature	:	…………………….
Author's Name	:	LOH YEN CHING
Date	:	5th June 2015

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the Degree of Manufacturing Engineering (Engineering Materials) (Hons.). The member of the supervisory committee is as follow:

……………………………………

(Supervisor)

(MOHD YUHAZRI BIN YAAKOB)

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: "Development and Analysis of New Intraply for Glass Fiber and Kenaf Fiber in Composite Structure Applications"

SESI PENGAJIAN: 2014/15 Semester 2

Saya **LOH YEN CHING**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
√	TIDAK TERHAD	

Disahkan oleh:

_______________________ _______________________

Alamat Tetap:

1016,Taman Indah, Jalan Kolam Air,

73000 Tampin, Negeri Sembilan

Tarikh: _______________________

Cop Rasmi:

Tarikh: _______________________

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

ABSTRAK

Kajian ini memberi tumpuan kepada kesan lapis tunggal atau hibrid *lamina* komposit *intraply* terhadap empat jenis tenunan yang berbeza struktur di bawah ujian ketumpatan permukaan, ujian tegangan yang membujur dan melintang. Semua komposit *lamina intraply* dihasilkan dengan menggunakan kaedah tekanan serapan dan dibina dari gentian kaca dan gentian kenaf sebagai serat dan resin epoksi sebagai bahan pengikat mengikut khusus empat jenis reka bentuk tenunan seperti anyaman biasa, 2x2 kepar, 5-kekerasan satin dan 2x2 bakul tenun. Gentian kenaf telah dianyam di arah meledingkan dan gentian kaca pada arah melintang. Penemuan untuk ujian tegangan membujur menunjukkan bahawa kepar tenunan menpunyai nilai daya yang maksimum tertinggi dan diikuti oleh 2x2 bakul anyaman, anyaman biasa. Manakala anyaman 5-kekerasan satin adalah 27.12 % lebih rendah berbanding dengan anyaman kepar. Kajian bagi melintang tegangan menunjukkan anyaman 2x2 bakul mempunyai nilai purata daya maksimum yang paling tinggi diikuti oleh 2x2 kepar, anyaman biasa dan anyaman 5- kekerasan satin. Nilai purata daya maksimum tertinggi adalah 3.12 kN untuk memisahkan anyaman 2x2 bakul sampel dan 37.82 % yang lebih tinggi daripada 5-kekerasan satin. Struktur anyaman yang berbeza dan peratusan kandungan gentian yang berbeza yang mana anyaman kepar dalam ujian tegangan yang membujur memerlukan daya maksimum yang tertinggi disebabkan struktur yang kompleks. Selain itu, kuasa maksimum anyaman 2x2 bakul adalah tertinggi dengan sebanyak 0.64 % berbanding dengan kepar tenunan kerana jumlah gentian kaca adalah tinggi. Anyaman 5- kekerasan satin menunjukkan nilai kuasa maksimum yang terendah dalam ujian tegangan membujur dan melintang kerana gentian meleding dan melintang agak rendah dan longgar. Hasil ujikaji mengesahkan bahawa kepadatan dalam struktur anyaman dan bilangan benang komposit akan memberi implikasi kepada sifat-sifat akhir komposit *lamina intraply*, struktur anyaman yang lebih padat, memerlukan daya yang lebih besar untuk memecahkan.

ABSTRACT

This research focuses on the effect of a single ply or lamina intraply hybrid composite in four different weave structure designs under areal density, longitudinal and transverse tensile test. The eight lamina intraply composite is fabricated by using vacuum infusion and the glass fiber and kenaf fiber as reinforcements and epoxy resin as matrix according to specific different weave structure designs which are plain weave, 2x2 twill weave, 5-hardness satin weave and 2x2 basket weave. The kenaf fibers were weaved in the warp direction and the glass fibers in weft direction. The findings for longitudinal tensile test shows the 2x2 twill weave design required highest average value of maximum force to break followed by 2x2 basket weave, plain weave and 5-hardness satin weave which is lowest 27.12 % compare to 2x2 twill weave. Meanwhile, the findings for transverse tensile test shows the 2x2 basket weave sample required highers average value of maximum force followed by 2x2 twill, plain and 5-hardness satin. The highest average value of maximum force is 3.12 kN to break the 2x2 basket weave sample which 37.82 % higher than 5-hardness satin. A different weave design structure and percentage of reinforcement content required a different breaking force where the twill weave in longitudinal tensile test needed highest force due to the complex structure of design. Besides, the 2x2 basket weave is slightly higher about 0.64 % of the maximum force compare to twill weave because the number of yarns of glass fiber in 2x2 basket weave is more than twill weave. The 5-hardness satin weave shows the lowest breaking force in longitudinal and transverse tensile test due to the intersections of warp and weft yarns are relatively lower and loosen. The experimental result confirmed that the compactness of the weave structure and the number of yarns in composite produce high effect on the properties of lamina intraply composite, the less loosen structure, the highest the breaking force required.

ACKNOWLEDGEMENT

Firstly, I am grateful that I have Dr. Mohd Yuhazri Bin Yaakob as my supervisor for my final year project who has been guiding me throughout the period of the final year project. I would like to thank for his patience and motivation while guiding me to a better track of conducting this project. His guidance on the report has helped me a lot as he has the willingness to sacrifice his time on checking my report words by words. I would also very appreciate him as he always shares his experience with us.

Besides, I would like to thank my friends who are also under the supervision of Dr. Mohd Yuhazri Bin Yaakob. Throughout the period of final year project, I am able to learn extra knowledge via discussion among each other. They always provide me cheers, comments and cooperation.

Finally, I would like to thank my family and friends who have been always giving me support and encouragement throughout the whole research of my final year project.

DEDICATION

Dedicated to my beloved father, Loh Sae Kong,
my appreciated mother, Wong Swee Moi
and my adored sisters, Loh Yen Nee, Loh Mei Ying and Loh Mei Chie
for giving me moral support, cooperation, encouragement and also understandings.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
KFRP	-	Kenaf Fiber-Reinforced Polymer
PSM	-	Projek Sarjana Muda
PC	-	Polycarbonate
PP	-	Polypropylene
PS	-	Polystrene
PVA	-	Poly (vinyl alcohol)
MEKP	-	Methyl ethyl ketone peroxide
S1/P1	-	Sample 1 in plain weave
S2/T2	-	Sample 2 in 2x2 twill weave
S3/H3	-	Sample 3 in 5-hardness satin weave
S4/B4	-	Sample 4 in 2x2 basket weave
UPE	-	Unsaturated polyester resin
RTM	-	Resin transfer molding
LCM	-	Liquid composite molding
NCF	-	Non-crimp fabric
UD	-	Uni-directional
UTM	-	Universal testing machine
SEM	-	Scanning electron microscopy
RM	-	Ringgit Malaysia

LIST OF SYMBOLS

^{o}	-	Degree
^{o}C	-	Degree celcius
kPa	-	Kilo pascal
MPa	-	Mega pascal
GPa	-	Giga pascal
K_{IC}	-	Fracture toughness
G_{IC}	-	Fracture energy
kg/cm^3	-	Kilogram per centimetre cubic
kg/m^2	-	Kilogram per metre square
kJ/m^2	-	Kilo joule per metre square
g/m^2	-	Gram per metre square
g/cm^3	-	Gram per centimetre cubic
$J\ m^{-2}$	-	Joule per meter square
$MPa\ m^{1/2}$	-	Mega pascal square root of metre
Mm/min	-	Millimetre per minute
m/s	-	Metre per second
µm	-	Micro metre
kg	-	Kilogram
kN	-	Kilo newton
X	-	Multiply
%	-	Percent
:	-	Ratio
mm	-	Millimetre
wt. %	-	Weight percent
min	-	Minute

CHAPTER 1

INTRODUCTION

1.1 Background of Research

In Malaysia, there are abundant natural fibers that are available which can be economically processed into natural fiber polymer composites. One of the natural fibers is kenaf fiber. This fiber gains became the top national commodity crop under the supervision of the Malaysian National Kenaf and Tobacco Board (Mansor *et al.,* 2013). This is due to the kenaf fiber has superior toughness and high aspect ratio compared to other natural fibers. In addition, kenaf based polymer composites can be produced using either thermoset or thermoplastic matrix.

In addition, the natural fiber is currently applied or mixed with synthetic fiber for composite material. The most common synthetic fiber used for polymer composites is glass fiber. This is due to the glass fiber has relatively low cost and good in mechanical properties. In order to reduce cost, this material is widely used in hybridization with other synthetic fibers while the hybridization with natural fiber will give positive effects on strengthening the tensile and compressive properties of natural fiber (Manap *et al.,* 2014). In brief, the effect of glass fiber in hybridization helps to enhance the properties of composite laminate (Jayabal *et al.*, 2011; Enfedaque *et al*., 2010).

Hybrid composites contain two or more different types of reinforcement materials which are bounded in the same matrix and depending on the way of constituents materials that are mixed together such as the fiber orientation. The most common hybrid composites used is interply hybrid where two or more layers homogeneous reinforcements are stacked together. Meanwhile, an intraply hybrid composite is tows of the two or more types of fibers interlaced in the same layer of matrix (Pegoretti *et al.,* 2004). The authors investigated an improvement in the specific ultimate properties of polymer fiber reinforced composites with inorganic brittle reinforcements such as the carbon or glass fiber that was attempted by the incorporation of more ductile organic fibers, such as aramid. Hani *et al.* (2011) studied the hybrid composite of woven coir and kevlar fiber in which coir fiber has the resistance to the high speed impact penetration by reducing the amount of synthetic fiber used in the composite.

Furthermore, Akhbari *et al*. (2008) presented that woven fabric which is also known as the bi-directional reinforcement composite that able to provide a certain properties advantage to the different fiber reinforced composite. The authors also stated that the equal and balanced properties in warp and weft directions will enhance the woven fabric to be stiffer and impact resistance compared with unidirectional fiber composite. Likewise, the hybrid woven fabric that is made of glass and polyester fiber has increased the buckling strength of composite. The hybrid composite shows a greater strain to failure and better integrity after final failure. However, the woven fabric composite will degenerate the strength of fibers in woven fabrics which caused by non-straight linearity of warp and weft yarns upon weaving process. Based on this case, a special high module material can be used to minimize the deficiency of composite structure (Kucher and Danil'chuk, 2012).

Since natural fiber composite has better ductility, toughness and increase tensile as well as flexural and impact strength significantly, Hani *et al.* (2013) commented that the random orientation of fibers and compressed mat and woven fabric composite by using synthetic types fiber will give more advantages in mechanical properties. Previously, Nassif (2012) investigated the different weft densities and plain, twill and satin weave designs were affected the mechanical and physical properties of micropolyester woven fabrics. The author summarized that the plain weave fabrics were superior to other designs in the breaking load, elongation, and the stiffness. In addition, satin weave fabrics have higher air permeability while in twill weave fabric has higher crease recovery.

The studies on the synthetic fiber reinforced woven fabric laminated composite such as glass, carbon, and kevlar were carried out by scholars a decade ago (Nassif, 2012; Chu and Chen, 2010; Enfedaque *et al.*, 2007; Saidpour and Oscar, 2006; Pegoretti *et al.*, 2004). The studies were carried out to analyze the material performance in different ply and fiber orientation in laminated composite. However, there is no scientific research on the intraply of fibers in lamina composite since the stacking sequence of lamina and fiber orientation in composite are related. Thus, the development a new intraply lamina composite using glass fiber and kenaf fiber in weave structure could be an interesting topic to be explored in detail for gaining more understanding under the mechanical testing and enhancing the mechanical and physical properties of the composite structure applications.

1.2 Problem Statement

Nowadays, composite laminates have many applications that is used in advanced engineering materials such as in aircrafts, civil engineering structures and sports equipment. The major advantage of a composite material is the ability of controlling fiber alignment which is by arranging the layers and the direction of the fiber. This is due to the laminated material requires strength and stiffness properties to a specific design conditions. The analysis of stress values showed an influence on the lamination angles of layers, and possibility of predicting the deformations and stresses in composite layers (Vnuvcec, 2005). Besides, Dubrovski and Cebasek (2005) stated that the method of bonding and finishing for each layer would be affecting the mechanical properties of the fabric composite. This is due to the constructional parameter of each lamina will be influenced. In addition, Zhang *et al.* (2012) found that hybrid composite laminates which reinforced with 50 % carbon fiber provides the best flexural properties by placing the carbon layers at the exterior. The alternating carbon and glass lamina in the hybrid composite provides the highest compressive and flexural strength. The authors also examined that the tensile strength that is insensitive to the stacking sequence. Furthermore, Chu and Chen (2010) used kevlar fiber in the woven fabric composites and designed in plain, twill, basket and satin structure which is then undergo the ballistic impact test. The authors showed that the satin woven fabric exhibited the weakest bulletproof properties in the tests because of weaker stability of its construction. This is due to of the interlocked structure of fabric composite has high stiffness and better vibration performance than the plain woven fabric. This was also analyzed by Lei *et al.* (2011) where the interlocked structure has increased the bending and reduces the bending variation among the warps.

Based on the above studies on the effect of lamina construction and the types of fiber reinforced polymer composite in hybrid composite, different types of weave pattern design in woven fabric composite will affect the composite properties. This study is carried out to optimize the usage of raw materials such as glass fiber and kenaf fiber to examine the various ratios of both reinforcements in lamina hybrid composite. Particularly, the fabrication of a single ply of composite is necessary to be conducted through the specific weave designs in order to investigate, analyze and evaluate the first ply failure of laminated composite structures under mechanical testing.

1.3 Objectives

The objectives that are needed to achieve in the research include:

(a) To fabricate a single ply or lamina intraply hybrid composite by using glass fiber and kenaf fiber as reinforcements and epoxy resin as matrix material according to specific different weave pattern designs.

(b) To evaluate the physical and mechanical properties of the lamina intraply hybrid composite based on the effect of warp and weft direction of fibers.

(c) To propose the effective fibers to be in warp and weft directions with its most effective weave pattern designs in composite.

1.4 Scope of Research

The research scopes are as follows:

(a) To study the properties of glass fiber and kenaf fiber as reinforcement material in composite structure.

(b) To determine the effects of intraply hybrid composite by using glass and kenaf fiber.

(c) To study the strength of a single ply or lamina intraply hybrid composite.

(d) To identify the effect of warp and weft direction of reinforcements in composite.

(e) To design appropriate ratio of fibers to be warp and weft directions and the different weave patterns for lamina composite.

(f) To evaluate the mechanical and physical properties of lamina intraply hybrid composite based on the weave pattern designs through longitudinal and transverse tensile test.

(g) To propose the effective weave structure of lamina intraply hybrid composite.

1.5 Rational of Research

During these recent decades, composite materials have grown steadily in the number of application and manage to conquer the new market since they have been proven themselves where they are able to act as weight reduce materials and cost effective. Natural fiber reinforced polymer is growing rapidly in term of their industrial application and fundamental research. They are able to be recycled, cheap and biodegradable. This is due to their availability, renewability, low density and cost which help to enhance the mechanical properties compared to glass and carbon fiber in manufacturing of composite, the dependency of glass fiber in composite is reduced significantly. This is because of the physical bonding where the rough surface of the kenaf fiber gives the better interlocking between matric and reinforcement.

Intraply hybrid composite is balanced in terms of strength, stiffness and mechanical properties. It also reduces the weight and cost, gives a better fatigue and impact resistance. Therefore, by creating a new possibility of intraply hybrid lamina composite which glass fiber and kenaf fiber as reinforcement, it is possible to obtain viable compromise between mechanical properties and cost in order to meet specified design requirement. Besides that, the new intraply hybrid lamina composite allows to generate deep understanding on the role of glass fiber and kenaf fiber in hybrid composite structure after undergo mechanical testing. It is also able to foster the interest to conduct research on intraply of different reinforcement in composite.

Based on the previous studies, various types of fibers and weaving structures focus on the multilayer laminate composite. However, the woven fabric composites have attracted a significant amount of attention due to their highly specific strength and stiffness. In this research, the intraply of glass fiber and kenaf fiber in woven lamina composite where the fabric deformed into desired weave patterns influence the mechanical and physical properties of the composite. This research can gain new knowledge on enhancing the advancement of engineering and technology and offer a cheaper and recyclable option reinforcements for the existing fiber reinforced composite.

1.6 Research Methodology

This research study is related to the development and analysis of the new intraply of glass fiber and kenaf fiber in the composite structure application. The flow chart in Figure 1.1 is to summarize the flow of whole research in order to achieve the objectives for this research.

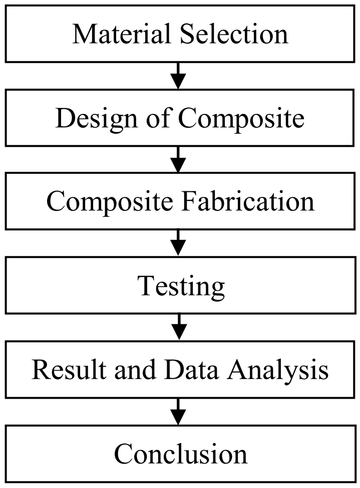

Figure 1.1: Flow chart of research methodology

This research methodology is starting with the selection of raw material. Glass fiber and kenaf fiber are chosen in this research to study the properties of lamina intraply hybrid composite. The thermoset epoxy resin is used as matrix to bind the reinforcements. Specific considerations are taken into account when selecting the matrix and reinforcement material such as the material properties, environmental effects and cost. The specific weave pattern designs and effect of fibers in the warp and weft direction of lamina composite are designed and investigated according to the objectives of this research. The sizes of the specimen samples are same for each test according to the American Society for Testing and Materials (ASTM). In this research, four different types of weave designs in lamina composite are tested on their properties. Each weave pattern design contains two samples which are divided into two categories that undergo longitudinal and transverse tensile test. The intraply hybrid composite designed in this research is a single ply, thus, the method of fabrication is by using the vacuum infusion after weave in a mat. Then, the lamina