PENGESAHAN PENYELIA

‘Saya/Kami* akui bahawa telah membaca
karya ini dan pada pandangan saya/kami* karya ini
adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan
Ijazah Sarjana Muda Kejuruteraan Mekanikal (Struktur dan Bahan)

Tandatangan	:	……………………...
Nama Penyelia	:	……………………...
Tarikh	:	………………………

*Potong yang tidak berkenaan

THE EFFECT OF WOVEN GLASS LAY-UP ORIENTATION ON FLEXURAL STRENGTH OF LAMINATED POLYMER COMPOSITE

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DECLARATION

I hereby declare that this project report entitled

THE EFFECT OF WOVEN GLASS LAY-UP ORIENTATION ON FLEXURAL STRENGTH OF LAMINATED POLYMER COMPOSITE

is written by me and is my own effort and that no part has been plagiarized without citations.

Signature	: ……………………...
Writer Name	: Nik Haidar bin Nik Abdullah.
Date	: 10th April 2009

DEDICATION

To my beloved parents,
Nik Abdullah Bin Nik Soh and Noridah Binti Husain.
Who inspired me with their love and kindness.

To Norahayu Binti Mohd Ramly,
For giving me endless strength and support.

To all my friends,
For giving me support and idea.

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ABSTRACT

Stacking plates of composite materials, which are common used today have increasing in demand because of its unique characteristics. It has the properties of uneven quality and anisotropic nature unlike general metallurgical materials as the staking plates of composite materials are in the combination of different types of fiber materials to produce continuous reinforced polymer composite such as laminated polymer composite. Therefore, in this study, stacking plates of laminated polymer composite materials were manufactured using hand lay-up, cured polyester resin, woven roving glass fiber and chopped strand mat. Then it is made by changing woven fiber glass orientation angles and also some samples in combination with chopped strand mat (CSM). The samples after that are tested in the thickness direction for six specimens, three with different fiber orientations, $[0/90/0/90]_{2S}$, $[0/90]_{2S}[0/45]_{2S}$, $[0/45/0/45]_{2S}$ and plus another three sample in orientation and combination, $[CSM/CSM]_{2S}$, $[CSM]_{2S}[0/90]_{2S}$, $[CSM]_{2S}[0/45]_{2S}$ which is chopped strand mat .In this study, it was to obtain the flexural strength results by carrying out three-point bending testing and in order to find out the effect of that orientation according to the samples by following the ASTM D790 test method.

ABSTRAK

Kepingan berlapis bahan komposit yang sering digunakan sehingga hari ini telah meningkat permintaannya disebabkan ciri-cirinya yang unik. Ianya mempunyai ciri-ciri kualiti yang berbeza dan mempunyai sifat anisotropik semulajadi tidak seperti bahan-bahan logam kerana kepingan berlapis ini terdiri daripada pelbagai kombinasi bahan gentian untuk menghasilkan kepingan polimer komposit yang diperkuatkan seperti polimer komposit berlamina. Oleh itu, dalam kajian ini kepingan berlapis polimer komposit berlamina tersebut akan dihasilkan menggunakan kaedah pembuatan manual dengan menggunakan tangan, damar polyester yang dipulihkan, anyaman gentian kaca pintal kasar dan potongan bebenang gentian kaca yang dijadikan seperti tikar. Lapisan berlamina ini kemudian dibuat dengan mengubah kedudukan anyaman kaca gentian tersebut mengikut sudut-sudut orientasi tertentu dan juga beberapa sampel dengan kombinasi potongan bebenang gentian kaca yang dijadikan seperti tikar. Spesimen selepas itu diuji dalam arah ketebalan untuk enam sampel, tiga dengan orientasi-orientasi gentian, $[0/90/0/90]_{2S}$, $[0/90]_{2S}[0/45]_{2S}$, $[0/45/0/45]_{2S}$ dan tiga sampel lagi dengan orientasi dan gabungan , $[CSM/CSM]_{2S}$, $[CSM]_{2S}[0/90]_{2S}$, $[CSM]_{2S}[0/45]_{2S}$ yang merupakan potongan damparan tikar. Dalam kajian ini juga, ia adalah untuk mendapatkan kekuatan lenturan dengan melaksanakan ujian tiga mata membengkok dan secara khususnya untuk mengetahui kesan orientasi itu kepada sampel-sampel dengan menggunakan kaedah ujian standard ASTM D790.

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σ_f	=	Flexural stress
F	=	load (force) at the fracture point
L	=	length of support span (mm)
b	=	Width of test beam (mm)
d	=	Depth of tested beam (mm)
ε_f	=	Flexural strain
D	=	maximum deflection of the center of the beam (mm)
M	=	Slope of the tangent to the initial straight-line portion of the **l**oad deflection curve, (N/mm)
E_b	=	Modulus of elasticity in bending,(MPa)

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Composite materials are used increasingly in various fields such as space and aviation industry, architectural structures, shipbuilding materials, sporting goods, and interior and structural materials of automobiles due to the excellence of mechanical characteristics as well as light weight, heat resistance, and control characteristics. Composite in its most basic form is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. Generally, most composite consist of bulk material or being called the matrix and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix. The reinforcement is usually in fiber form. Today, there are three main group most common man-made composites such as Fiber Reinforced Polymer (FRP), Metal Matrix Composites (MMC's) and Ceramic Matrix Composites (CMC's) (McCauley, 1991). This study will make use of FRP that used cured polyester resin, fiber of woven fiber glass and chopped strand mat as the reinforcement. FRP composites is defined as a polymer or plastic matrix, either thermoset or thermoplastic, that is reinforced with a fiber or reinforcing material with a sufficient aspect ratio to provide a discernable reinforcing functions in one or more directions (Miracle, 2001). FRP composites are anisotropic whereas metallurgy material is isotropic. Therefore, FRP composite or also can be called laminated polymer composite properties are directional, meaning that the best mechanical properties are in direction of the fiber placement (Miller, 1998). In that case, in this flexural study, by carrying out three-point bending testing according to ASTM D790, six specimens, three with different fiber orientations, $[0/90/0/90]_{2S}$, $[0/90]_{2S}[0/45]_{2S}$, $[0/45/0/45]_{2S}$ and plus another three sample in orientation and combination, $[CSM/CSM]_{2S}$, $[CSM]_{2S}[0/90]_{2S}$, $[CSM]_{2S}[0/45]_{2S}$ which is chopped strand mat. Processing data that can be referenced in the examination study of flexural strength characteristics of specimen's composite materials are presented.

1.2 Objective

This study is about to identify and find out the effect of different orientation woven fiber glass lay-up and combination chopped strand mat to the flexural strength of laminated polymer composite or FRP using three point bending test according to standard test method, ASTM D790.

1.3 Scopes

The scopes of this study are:

i) To understand about laminated composite mechanical properties in different orientation of woven fiber-glass and combination layer of chopped strand mat.
ii) To fabricate specimens according the standard three point bending flexural test method.
iii) To expose and conduct three point bending flexural test method according ASTM D 790 standard.
iv) To compare differential in flexural strength properties for each specimens

1.4 Problem Statement

In general, laminated polymer composites have many benefits to their selection and use. The selection of the material depends on performance and intended use of the product. The composites designer can tailor the performances of the end product with proper selection of material. It is important for the end-user to understand the application environment, load performance and durability requirements of the product and convey this information to the composite industrial professional. Since laminated composite categories into isotropic material, it strength depends on manufacturing technique, which is the combination between it bulk material, orientation and matrix material will give it own value to mechanical properties such as strength. Therefore this study will focus to know the effect of different combination orientation woven fiber glass and chopped strand mat to its flexural properties in making laminated polymer composite.

CHAPTER 2

LITERATURE REVIEW

Chapter two will describe about literature review on FRP or laminated polymer composite, resin and woven roving glass fiber. Some information about mechanical properties focus on flexural properties and modulus for this laminated composite will be mentioned in this chapter. Furthermore three points bending test also will be explained in addition to ASTM standard that will be used in this study.

2.1 Fiber Reinforced Polymer

Many terms have been used to define FRP composites. Modifiers have been used to identify a specific fiber such as Glass Fiber Reinforced Polymer (GFRP), Carbon Fiber Reinforced Polymer (CFRP), and Aramid Fiber Reinforced Polymer (AFRP) (McCauley, 1991). Another familiar term used is Fiber Reinforced Polymer (FRP) or laminated polymer composite. In addition, other acronyms were developed over the years and its use depended on fiber or material been used or market target. For example, Fiber Reinforced Composites (FRC), Glass Reinforced Plastics (GRP), and Polymer Matrix Composites (PMC) can be found in many references. Although different, each of mentioned terms mean the same thing; FRP composites (Miracle, 2001).

2.1.1 Benefits

FRP composites have many benefits to their selection and use. The selection of the materials depends on the performance and intended use of the product. The composites designer can tailor the performance of the end product with proper selection of materials. It is important for the end-user to understand the application environment, load performance and durability requirements of the product and convey this information to the composites industry professional. A summary of composite material benefits include:

- Light weight
- High strength-to-weight ratio
- Directional strength
- Corrosion resistance
- Weather resistance
- Dimensional stability
    - low thermal conductivity
    - low coefficient of thermal expansion
- Radar transparency
- Non-magnetic
- High impact strength
- High dielectric strength (insulator)
- Low maintenance
- Long term durability
- Part consolidation
- Small to large part geometry possible
- Tailored surface finish

2.1.2 Compositions

Composites are composed of resins, reinforcement's fiber or with fillers and additives addition. Each of these constituent materials or ingredients plays an important role in the processing and final performance of the end product. The resin or polymer is the "glue" that holds the composite together and influences the physical properties of the end product. The reinforcement provides the mechanical strength. The fillers and additives are used as process or performance aids to impart special properties to the end product. The type and quantity of materials selected in addition to the manufacturing process to fabricate the product, will affect the mechanical properties and performance. Important considerations for the design of composite products include:

- Type of fiber reinforcement (glass, carbon or Kevlar)
- Percentage of fiber or fiber volume (30% fiber /or 50% fiber)
- Orientation of fiber (0°,±45°, 90° or a combination of these)
- Type of resin (polyester, epoxy)

2.1.3 Resins

The primary functions of the resin are to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage. Resins are divided into two major groups known as thermoset and thermoplastic. Thermoplastic resins become soft when heated, and may be shaped or molded while in a heated semi-fluid state and become rigid when cooled. Thermoset resins, on the other hand, are usually liquids or low melting point solids in their initial form. When used to produce finished goods, these thermosetting resins are "cured" by the use of a catalyst, heat or a combination of the two. Once cured, solid thermoset resins cannot be converted back to their original liquid form. Unlike thermoplastic resins, cured thermosets will not melt and flow but will soften when heated (and lose hardness) and once formed they cannot be reshaped. The most common thermosetting resins used in the composites industry are unsaturated polyesters, epoxies, vinyl esters and phenolics. There are differences between these groups that must be understood to choose the proper material for a specific application (Murphy, 1998).

2.1.3.1 Polyester

Unsaturated polyester resins (UPR) are the workhorse of the composites industry and represent approximately 75% of the total resins used. To avoid any confusion in terms, readers should be aware that there is a family of thermoplastic polyesters that are best known for their use as fibers for textiles and clothing. Thermoset polyesters are produced by the condensation polymerization of dicarboxylic acids and difunctional alcohols (glycols). In addition, unsaturated polyesters contain an unsaturated material, such as maleic anhydride or fumaric acid, as part of the dicarboxylic acid component. The finished polymer is dissolved in a reactive monomer such as styrene to give a low viscosity liquid. When this resin is cured, the monomer reacts with the unsaturated sites on the polymer converting it to a solid thermoset structure (Murphy, 1998).

A range of raw materials and processing techniques are available to achieve the desired properties in the formulated or processed polyester resin. Polyesters are versatile because of their capacity to be modified or tailored during the building of the polymer chains. They have been found to have almost unlimited usefulness in all segments of the composites industry. The principal advantage of these resins is a balance of properties (including mechanical, chemical, electrical) dimensional stability, cost and ease of handling or processing. Unsaturated polyesters are divided into classes depending upon the structures of their basic building blocks. Some common examples would be orthophthalic ("ortho"), isophthalic ("iso"), dicyclopentadiene ("DCPD") and bisphenol A fumarate resins. In addition, polyester resins are classified according to end use application as either general purpose (GP) or specialty polyesters (Murphy, 1998).

Polyester producers have proved willing and capable of supplying resins with the necessary properties to meet the requirements of specific end use applications. These resins can be formulated and chemically tailored to provide properties and process compatibility (Murphy, 1998).

2.1.3.2 Summary of Resins

The resins in thermoset composites are an important source of properties and process characteristics. One of the great design strengths of composites is the multiple choices of resins. In order to make effective use of these choices, designers and product specifiers should be familiar with the properties, advantages and limitations of each of the common composite resins. It is common to use the resources of the resin manufacturer's laboratories to determine the best resin or an application but in this research study the resin that have been choices is a versatile quick curing unsaturated polyester resin or ortho-phthalic type. This cured resin has good mechanical properties, thixotropic, unwaxed and accelerated. Hence, also really suitable for both hand lay-up and spray-up process (Miracle, 2001).

2.1.4 Reinforcements

The primary function of fibers or reinforcements is to carry load along the length of the fiber to provide strength and stiffness in one direction. Reinforcements can be oriented to provide tailored properties in the direction of the loads imparted on the end product. Reinforcements can be both natural and man-made. Many materials are capable of reinforcing polymers. Some materials, such as the cellulose in wood, are naturally occurring products. Most commercial reinforcements, however, are man-made and so far the largest volume reinforcement measured either in quantity consumed or in product sales, is glass fiber. Other composite reinforcing materials include carbon, aramid, UHMW (ultra high molecular weight) polyethylene, polypropylene, polyester and nylon. Carbon fiber is sometimes referred to as graphite fiber. The distinction is not important in an introductory text, but the difference has to do with the raw material and temperature at which the fiber is formed. More specialized reinforcements for high strength and high temperature use include metals and metal oxides such as those used in aircraft or aerospace applications.

2.1.4.1 Development of Reinforcements - Glass Fibers

Early in the development of composites, the only reinforcements available were derived from traditional textiles and fabrics. Particularly in the case of glass fibers, experience showed that the chemical surface treatments or "sizings" required processing these materials into fabrics and other sheet goods were detrimental to the adhesion of composite polymers to the fiber surface. Techniques to remove these materials were developed, primarily by continuous or batch heat cleaning. It was then necessary to apply new "coupling agents" (also known as finishes or surface treatments), an important ingredient in sizing systems, to facilitate adhesion of polymers to fibers, particularly under wet conditions and fiber processing. Most reinforcements for either thermosetting or thermoplastic resins receive some form of surface treatments, either during fiber manufacture or as a subsequent treatment. Other materials applied to fibers as they are produced include resinous binders to hold fibers together in bundles and lubricants to protect fibers from degradation caused by process abrasion (Miracle, 2001).

Based on an alumina-lime-borosilicate composition, "E" glass produced fibers are considered the predominant reinforcement for polymer matrix composites due to their high electrical insulating properties, low susceptibility to moisture and high mechanical properties. Other commercial compositions include "S" glass, with higher strength, heat resistance and modulus, as well as some specialized glass reinforcements with improved chemical resistance, such as AR glass (alkali resistant) (Miller, 1998).

Glass fibers used for reinforcing composites generally range in diameter from 0.00035" to 0.00090" (9 to 23 microns). Fibers are drawn at high speeds, approaching 200 miles per hour, through small holes in electrically heated bushings. These bushings form the individual filaments. The filaments are gathered into groups or bundles called "strands." The filaments are attenuated from the bushing, water and air cooled, and then coated with a proprietary chemical binder or sizing to protect the filaments and enhance the composite laminate properties. The sizing also determines the processing characteristics of the glass fiber and the conditions at the fiber-matrix interface in the composite (Miller, 1998).