EFFECT OF DIFFERENT BUILD ORIENTATION ON MECHANICAL PROPERTIES OF FIBERGLASS REINFORCED COMPOSITE

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To my beloved father and mother

Mr.Muhamad Atan Bin Awang

Mrs Juhani Binti Othman

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ABSTRACT

This thesis deals with effect of different build orientation on mechanical properties of fibreglass reinforced composite. The objective of this thesis is to investigate the mechanical properties of fibreglass reinforced composite with different build orientation, investigate the relation between fibreglass and polyester resin, and to understand on the mechanical behaviour of fibreglass reinforced composite. Fibreglass is refer to a group of products made from individual glass fibres combined into a variety of forms and act as reinforcing agent. The problem of bonding between fibreglass and the matrix resin affect the strength of the fibreglass reinforced composite and this need to be deals with the study on their mechanical properties by using mechanical experiment test. The test is carried out using tensile test, which all are focusing on investigating mechanical properties on the specimens. Fibreglass reinforced composite is made up by using hand lay-up technique, where different laminate of fibreglass made up by different build orientation of fibreglass which result different strength. The aim of the test is to study on this fibreglass reinforced composite strength and to observed on the mechanical behaviour of this material. It was found that by arranging the fibreglass properly, the stronger the fibreglass reinforced composite be.

ABSTRAK

Tesis ini membentangkan kesan daripada berlainan orientasi binaan kepada fiber-reinforced plastic (FRP). Objektif tesis ini ialah untuk mengkaji sifat mekanikal FRP dengan berlainan orientasi bahan gentian kaca, menyiasat hubung kait antara bahan gentian kaca dengan bahan penguat, serta memahami sifat laku mekanikal bahan tersebut. Plastik yang diperkukuh, atau dikenali sebagai FRP ini mempunyai bahan gentian kaca didalamnya. Masalah yang timbul di antara ikatan gentian kaca dan bahan penguat resin menjejaskan kekuatan bahan ini, dan tesis ini membincangkan sifat mekanikal bahan ini dengan cara menjalankan eksperimen. Eksperimen yang dijalankan iaitu, 'tensile test' memfokuskan kajian tentang sifat-sifat mekanikal yang ditunjukkan oleh specimen. FRP ini dihasilkan sendiri menggunakan tangan melalui teknik 'tindih dan tindih', yang mana orientasi bahan gentian kaca yang berbeza, akhirnya mempunyai kekuatan berlainan. Tujuan dijalankan eksperimen ini ialah bagi mengukur kekuatan bahan dan melihat sendiri perubahan yang berlaku terhadap FRP ini apabila dikenakan daya. Ianya diketahui bahawa menyusun bahan gentian kaca dengan betul, maka makin kuat bahan tersebut.

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LIST OF SYMBOLS

σ	Engineering Stress
ε	Engineering strain
δ	Change in the specimen’s gage length
L_o	Original gage length
σ_{ut}	Ultimate Tensile Strength
σ_y	Yield Stress
°C	Degree Celcius
ºF	Degree Fahrenheit
mm	millimeter
MPa	Mega Pascal
%	percentage
kN	Kilonewton
P	Applied Load
A_O	Original cross sectional area
E	Young’s Modulus

LIST OF ABBREVIATIONS

GFRP	Glass Fiber Reinforced Polymer
PMCs	Polymer Matrix Composites
CFRP	Carbon Fiber Reinforced Polymer
ASTM	American Society for Testing and Materials
FRP	Fiber Reinforced Plastic
GRE	Glass Fibre Reinforced Epoxy
R&D	Research and Development
RF	Radio Frequency
UTS	Ultimate Tensile Strength
PVC	Polyvinyl Chloride
PE	Polyethylene
PP	Polypropylene
UP	Unsaturated Polyester
PURs	Polyurethenas

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The term composite could mean almost anything if taken at face value, since all materials are composed of dissimilar subunits if examined at close enough detail. But in modern materials engineering, the term usually refers to a “matrix" material that is reinforced with fibres. For instance, the term “FRP" (for Fibre Reinforced Plastic) usually indicates a thermosetting polyester matrix containing glass fibres, and this particular composite has the lion's share of today's commercial market.

Many composites used today are at the leading edge of materials technology, with performance and costs appropriate to ultra demanding applications such as spacecraft. But heterogeneous materials combining the best aspects of dissimilar constituents have been used by nature for millions of years. Ancient society, imitating nature, used this approach as well: the Book of Exodus speaks of using straw to reinforce mud in brick making, without which the bricks would have almost no strength. The fibres used in modern composites have strengths and stiffness far above those of traditional bulk materials. The high strengths of the glass fibres are due to processing that avoids the internal or surface flaws which normally weaken glass, and the strength and stiffness of the polymeric aramid fibre is a consequence of the nearly perfect alignment of the molecular chains with the fibre axis. Of course, these materials are not generally usable as fibres alone, and typically they are impregnated by a matrix material that acts to transfer loads to the fibres, and also to protect the fibres from abrasion and environmental attack. The matrix dilutes the properties to some degree, but even so very high specific (weight-adjusted) properties are available from these materials. Metal and glass are available as matrix materials, but these are currently very expensive and largely restricted to R&D laboratories. Polymers are much more commonly used, with unsaturated styrene-hardened polyesters having the majority of low-to-medium performance applications and epoxy or more sophisticated thermosets having the higher end of the market.

1.2 OBJECTIVES OF STUDY

i. To investigate the mechanical properties of fibreglass reinforced composite with different build orientation.

ii. To determine the mechanical strength (tensile strength) of fibreglass reinforced composite.

1.3 SCOPES OF PROJECT

i. To prepare the sample specimen based on different orientation of fibreglass which are 0°, 90° and random.

ii. To examine the strength of the specimen by tensile test method using Universal Testing Machine.

iii. To determine the specimen with the highest ultimate strength.

1.4 PROBLEM STATEMENT

Composites usually used in high technology application because of their hardness and strength. However, fibre orientation in composite will affect the composite strength in which different build of orientation will be used. Stress distribution will be varied according to the orientation of fibre.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the importance and application of the composite materials at several sectors will be discussed. This chapter will inquired into the general properties of the components that commonly used to produce polymer composite materials which are fibre glass, polyester and epoxy. Through this chapter, the details of the composite materials can be understood in depth. The roles of build orientation in mechanical properties of the composite materials also can be studied deeply. Hence, a suitable composition of fibre and resin can be investigated to produce composite materials with better performance.

2.2 COMPOSITE

Practically everything is a composite material in some sense. For example, a common piece of metal is a composite (polycrystal) of many grains (or single crystals).
A composite material:

> Consists of two or more physically and/or chemically distinct, suitably arranged or distributed phases, with an interface separating them. It has characteristics that are not depicted by any of the components in isolation (D. Calllister William, 1985).

Most commonly, composite materials have a bulk phase, which is continuous, called the matrix, and one dispersed, non-continuous, phase called the reinforcement, which is usually harder and stronger.

The concept of composite materials is ancient: to combine different materials to produce a new material with performance unattainable by the individual constituents. An example is adding straw to mud for building stronger mud walls. Some more recent examples, but before engineered materials became prominent, are carbon black in rubber, steel rods in concrete, cement/asphalt mixed with sand, fibreglass in resin etc. In nature, examples abound: a coconut palm leaf, cellulose fibres in a lignin matrix (wood), collagen fibres in an apatite matrix (bone) etc.

The essence of the concept of composites is this: the bulk phase accepts the load over a large surface area, and transfers it to the reinforcement, which being stiffer, increases the strength of the composite. The significance here lies in that there are numerous matrix materials and as many fibre types, which can be combined in countless ways to produce just the desired properties.

Most research in engineered composite materials has been done since 1965. Today, given the most efficient design, of say an aerospace structure, a boat or a motor, we can make a composite material that meets or exceeds the performance requirements. Most of the savings are in weight and cost. These are measured in terms of ratios such as stiffness/weight, strength/weight, etc.

2.2.1 Definition of composite materials

The definition of a composite depends on the context. Composites are materials that utilize the combination of its constituents to increase a desired performance characteristic. Using this definition, the pearlitic steels may be thought of as a composite material formed by the combination of ferrite and cementite phases in alternating lamellae. The hard, brittle cementite combines with the soft, ductile ferrite to form a composite that has reasonably high strength along with some ductility. The present discussion will not focus on these naturally occurring composites, but rather those that are man made. These have phases that are chemically dissimilar and have a definite interface. Composites such as these have been developed to improve the strength, stiffness, and toughness of available materials.

A composite material may consist of many materials put together in many different ways. A simple example is material consisting of two phases. The matrix phase is continuous and forms the shape in which the dispersed phase acts as a constituent. There are different types of dispersed phase. It can be of a particle nature, meaning each particle is equiaxed, or it can be of a fibrous nature, where the dispersed phase is a filament. The type of dispersed phase, its orientation (for the fibrous type), size, relative amounts, and material properties will all affect the properties of the overall material.

2.2.2 Classification of composite types

Composite are classified by the geometry of the reinforcement

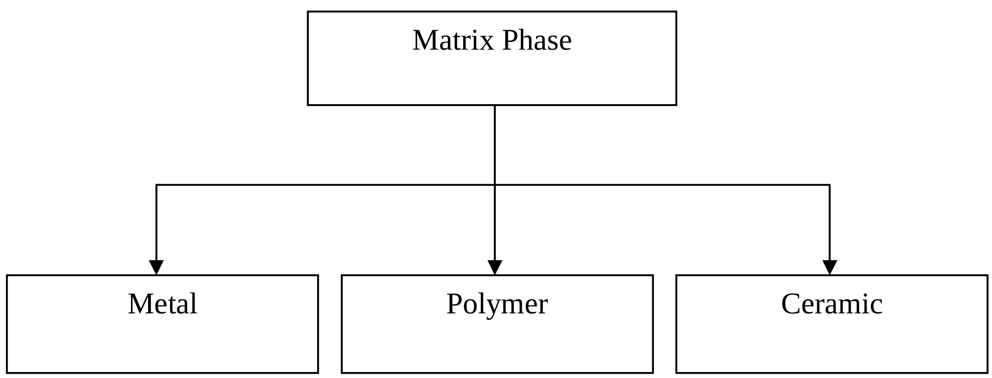


Figure 2.1: Matrix phase

The matrix phase is an essential part of the composite composition. Matrix materials can consist of a metal, polymer or a ceramic. Polymer matrices are the most common followed by metal and ceramics. The matrix phase has several important functions with respect to fibreous reinforced composites. The matrix acts to hold all reinforcements together thereby allowing the applied force to transmit to the reinforcement (L. Lehman Richard, 1999).

The matrix, due to its inherent ductility, does not carry a significant portion of the applied load. Instead the load is transmitted to the fibres. In order for this to occur the composite constituents must have a high fibre to matrix strength ratio. This can be seen in Figure 2 below.

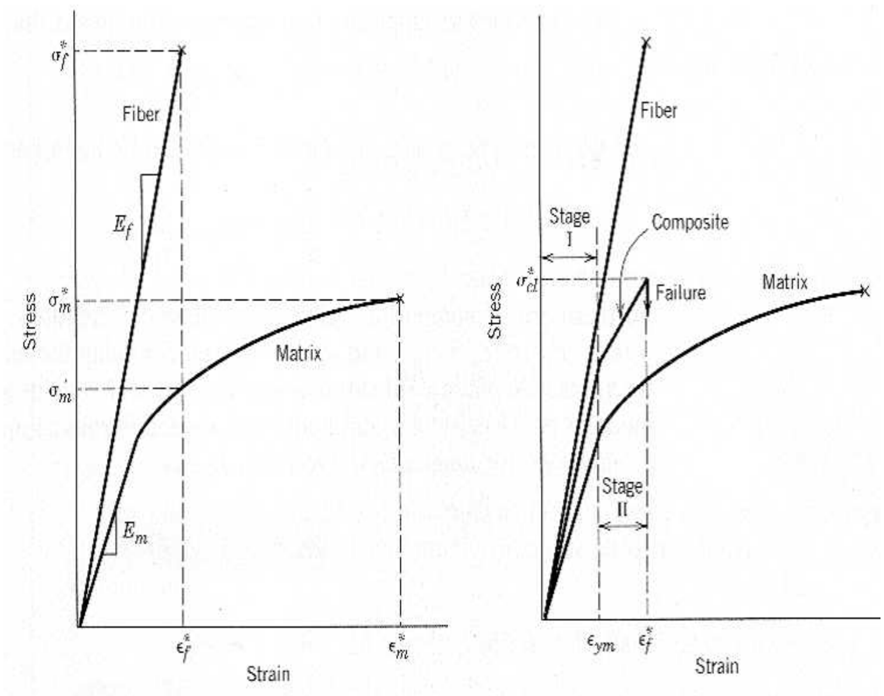


Figure 2.2: Stress –Strain curves of composite constituents

Other functions of the matrix include protection of the composite fibres from damage and to prevent crack propagation within the material. Adhesive bonding forces between the fibres and the matrix are essential in preventing separation of the two materials. This separation of the fibre from the matrix is called "pull-out". The bonding force between the two phases must be large to prevent this from occurring. Bonding forces play an important role in the overall load carrying characteristics of the material.

2.3 POLYMER-MATRIX COMPOSITES (PMCs)

i. Matrix made from a polymer resin
ii. Fibres act as reinforcement mechanism
iii. Most widely used of all composites
iv. Low cost / Easily manufactured

Polymer-matrix composites (PMCs) can be grouped in three different categories. The grouping is based to a large degree on the type of fibre reinforcement utilized in the composite matrix. A variety of polymers may be used for each type of PMC. The three groups are glass fibre-reinforced polymer (GFRP), carbon fibre-reinforced polymer (CFRP), and aramid fibre-reinforced polymer composites (Peter Morgan, 2005). This grouping is shown in Figure 3.

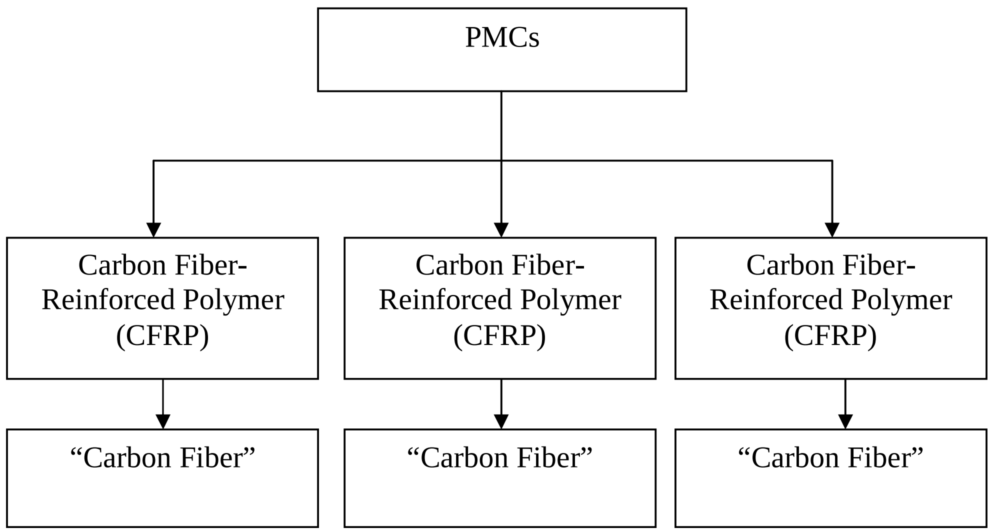


Figure 2.3: Grouping of polymer-matrix composites

2.4 GLASS FIBRE-REINFORCED POLYMER COMPOSITES (GFRP)

Glass fibre-reinforced polymer composites (GFRP), commonly known as fibreglass composites are the most widely used of all composites. GFRP is fibre-reinforced plastic made of a plastic reinforced by fine fibres made of glass . The plastic is thermosetting, most often polyester or vinylester, but other plastics, like epoxy (GRE), are also used.

2.4.1 Applications

GFRP is an immensely versitile material which combines lightweight with inherent strength to provide a weather resistant finish, with a variety of surface texture and an unlimited colour range available (Loewenstein, 1973).

GFRP was developed in the UK during the Second World War as a replacement for the molded plywood used in aircraft radomes (GFRP being transparent to microwaves). Its first main civilian application was for building of boats, where it gained acceptance in the 1950s. Its use has broadened to the automotive and sport equipment sectors, although its use there is being taken over by carbon fibre which weighs less per given volume and is stronger both by volume and by weight. GFRP uses also include hot tubs, pipes for drinking water and sewers, office plant display containers and flat roof systems.

Advanced manufacturing techniques such as pre-pregs and fibre rovings extend the applications and the tensile strength possible with fibre-reinforced plastics.

GFRP is also used in the telecommunications industry for shrouding the visual appearance of antennas, due to its RF permeability and low signal attenuation properties. It may also be used to shroud the visual appearance of other equipment where no signal permeability is required, such as equipment cabinets and steel support structures, due to the ease with which it can be molded, manufactured and painted to custom designs, to blend in with existing structures or brickwork. Other uses include sheet form made electrical insulators and other structural components commonly found in the power industries (Dominick V Rosato, 2004).

2.4.2 Physical properties

The properties of GFRP composites are measured the same way that traditional materials are measured so that comparisons can be made for evaluation. Typical measurements include:

Impact Strength –There are two primary impact tests; one is called IZOD impact and the other is called Charpy impact. IZOD impact measures the energy required to fracture or break a material when it is struck on its edge. Charpy impact measures the energy required to damage or puncture a material when it is struck on its front surface.

Tensile Strength– Measures how much of a load a material can take before it fractures or breaks when it is in the process of being stretched (Yunkai Lu, 2002).

2.5 FIBREGLASS

Fibreglass, (also called fibreglass and glass fibre), is material made from extremely fine fibres of glass. It is used as a reinforcing agent for many polymer products; the resulting composite material, properly known as fibre-reinforced plastic (FRP) or glassfibre-reinforced plastic (GFRP), is called "fibreglass" in popular usage. Glassmakers throughout history have experimented with glass fibres, but mass manufacture of fibreglass was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibres with the diameter and texture of silk fibres. This was first worn by the popular stage actress of the time Georgia Cayvan.

What is commonly known as "fibreglass" today, however, was invented in 1938 by Russell Games Slayter of Owens-Corning as a material to be used as insulation. It is marketed under the trade name Fibreglas, which has become a genericized trademark. A somewhat similar, but more expensive technology used for applications requiring very high strength and low weight is the use of carbon fibre.

Figure 2.4: Bundle of fibreglass

2.5.1 Formation

Glass fibre is formed when thin strands of silica-based or other formulation glass is extruded into many fibres with small diameters suitable for textile processing. Glass, even as a fibre, has little crystalline structure (see amorphous solid). The properties of the structure of glass in its softened stage are very much like its properties when spun into fibre. One definition of glass is "an inorganic substance in a condition which is continuous with, and analogous to the liquid state of that substance, but which, as a result of a reversible change in viscosity during cooling, has attained so high a degree of viscosity as to be, for all practical purposes, rigid (Loewenstein, 1973)."

The technique of heating and drawing glass into fine fibres has been known for millennia; however, the use of these fibres for textile applications is more recent. Until this time all fibreglass had been manufactured as staple. When the two companies joined to produce and promote fibreglass, they introduced continuous filament glass fibres (Loewenstein, 1973). Owens-Corning is still the major fibreglass producer in the market today.The first commercial production of fibreglass was in 1936. In 1938, Owens-Illinois Glass Company and Corning Glass Works joined to form the Owens-Corning Fibreglas Corporation. Two types of fibreglass most commonly used are S-glass and E-glass. E-glass has good insulation properties and it will maintain its properties up to 1500 º F(815 °C). S-glass has a high tensile strength and is stiffer than E-glass.

2.5.2 Properties

Glass fibres are useful because of their high ratio of surface area to weight. However, the increased surface area makes them much more susceptible to chemical attack. By trapping air within them, blocks of glass fibre make good thermal insulation, with a thermal conductivity of the order of 0.05 W/(mK) (David P. De Witt,1990).

Glass strengths are usually tested and reported for "virgin" fibres: those which have just been manufactured. The freshest, thinnest fibres are the strongest because the thinner fibres are more ductile. The more the surface is scratched, the less the resulting tenacity (Volf, Milos B, 1990).. Because glass has an amorphous structure, its properties are the same along the fibre and across the fibre (Gupta, 1997). Humidity is an important factor in the tensile strength. Moisture is easily adsorbed, and can worsen microscopic cracks and surface defects, and lessen tenacity.

In contrast to carbon fibre, glass can undergo more elongation before it breaks (Gupta, 1997). There is a correlation between bending diameter of the filament and the filament diameter (Melliand Textilberichte, 1969). The viscosity of the molten glass is very important for manufacturing success. During drawing (pulling of the glass to reduce fibre circumference), the viscosity should be relatively low. If it is too high, the fibre will break during drawing. However, if it is too low, the glass will form droplets rather than drawing out into fibre.

2.5.3 Uses

Uses for regular fibreglass include mats, thermal insulation, electrical insulation, reinforcement of various materials, tent poles, sound absorption, heat- and corrosion-resistant fabrics, high-strength fabrics, arrows, bows and crossbows, translucent roofing panels, automobile bodies, electrical insulation and boat hulls.

2.6 POLYMER

A polymer is a large molecule (macromolecule) composed of repeating structural units typically connected by covalent chemical bonds. While polymer in popular usage suggests plastic, the term actually refers to a large class of natural and synthetic materials with a variety of properties. There are two basic types of plastics/polymers: thermoplastic and thermoset.

In general, FRP composites utilize a thermoset plastic. In addition to these basic characteristics, polymers provide the FRP composite designer with a myriad of characteristics that can be selected, depending on the application. Combined with reinforcement of the polymer matrix, a vast range of characteristics are available for FRP composites

2.6.1 Thermoplastic

A plastic in which the polymer molecules are not crosslinked (not chemically bonded to other polymer molecules) is a thermoplastic. Since the molecules are not connected by crosslinks, it allows the molecules to spread farther apart when the plastic is heated. This is the basic characteristic of a thermoplastic; the plastic will soften, melt, or flow when heat is applied. Melting the plastic and allowing it to cool within a mold will form the finished product. Typical thermoplastics are: polyethylene (PE)– used in making garbage bags; polyvinyl chloride (PVC)– used for house siding; and polypropylene (PP)– used as carpet fibres, packaging, and diapers (Michel Biron, 2004).

2.6.2 Thermoset

A plastic in which the polymer molecules are crosslinked (chemically bonded) with another set of molecules to form a "net like" or "ladder-like" structure is a thermoset. Once crosslinking has occurred, a thermoset plastic does not soften, melt, or flow when heated. However, if the crosslinking occurs within a mold, the shape of the mold will be formed. Typical thermoset plastics are: unsaturated polyester (UP)– used for bowling balls and boats; epoxy– used for adhesives and coatings; and polyurethanes (PURs)– used in foams and coatings.

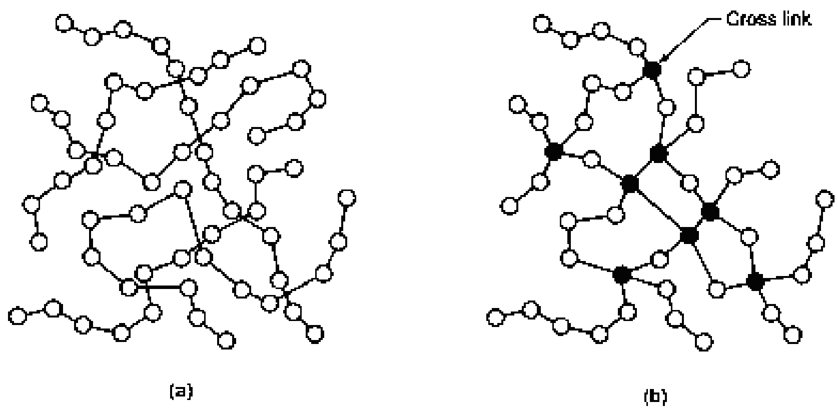


Figure 2.5: (a) Thermoplastic ,(b) Thermoset

2.7 UNSATURATED POLYESTER

Unsaturated polyester are obtained by the reaction between di-acids or anhydrides containing a proportion of double bonds and diol or glycol. The unsaturated polyesters can be modified, for example with:

i. Melamines
ii. Isocyanates

Consequently, the neat unsaturated polyester resins have varied properties that filling and reinforcement diversify even more to lead to a very broad range of characteristics and uses. Unless otherwise specified, the indications that follow relate to the most current types.

2.7.1 Mechanical properties

The mechanical properties, rigidity, impact resistance and creep are very variable according to the grades and the reinforcements. However, generally, the behavior is satisfactory and allows many mechanical application applications as composite matrices. Figure 6, and 7 indicates the general evolution of the main mechanical properties of the resins and composites as the fraction and the length of fibre increase.

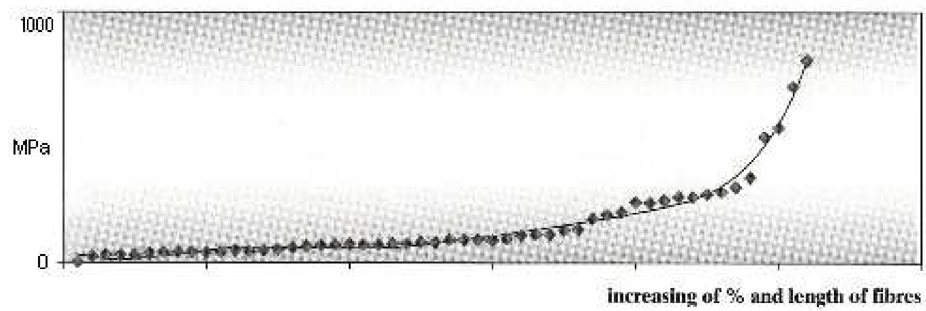


Figure 2.6: Unsaturated polyester. Tensile strength versus % and length of fibre

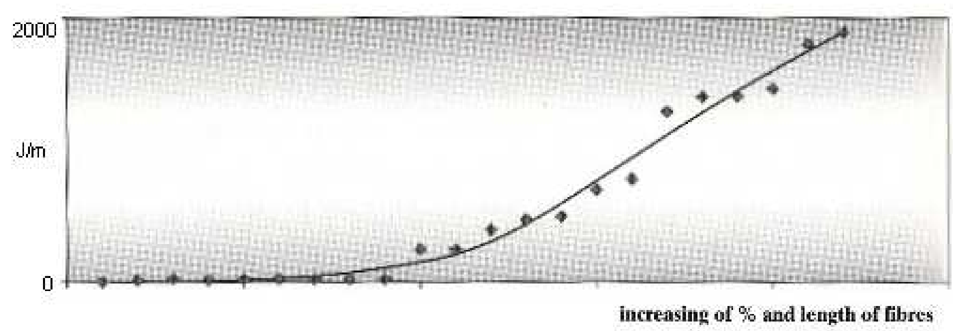


Figure 2.7: Unsaturated polyester. Notched impact versus % and length of fibre

2.7.2 Uses

The unsaturated polyester are the first class matrix for general purpose, mass-produced composites with a good technical level, generally with glass fibre reinforcement:

shipbuilding, automotive and railway bodies, anti-corrosive, electricity, tank, etc (Michel Biron, 2007).

2.8 EXPERIMENT METHOD

2.8.1 Tensile Test

Tensile test is used to evaluate the strength of composite. In this test a composite sample is pulled to failure in a relatively short time at a constant rate. Before testing, two small punch marks are identified along the specimen's length. The ability of a material to resist breaking under tensile stress is one of the most important and widely measured properties of materials used in structural applications.

Using the recorded data, the nominal or engineering stress is found by dividing the applied load P by the specimen's original cross sectional area, A_0 .

$$\sigma = \frac{P}{A_0} \tag{2.1}$$

The nominal or engineering strain is found by dividing the change in the specimen's gage length, δ ($\delta = L - L_0$) by the specimen's original gage length, L_0

$$\varepsilon = \frac{\delta}{L_0} \tag{2.2}$$

The resulting curve is called the stress-strain diagram. The yield strength, ultimate tensile strength, breaking strength and elastic or of a material can all be determined from this curve. The curve shown in Figure 2.8 is typical of metallic behavior. At small strain values (the elastic region), the relationship between stress and strain is nearly linear. Within this region, the slope of the stress-strain curve is defined as the elastic modulus. The point at which this line intersects the curve is called the yield point or the yield stress. The ultimate tensile strength, in contrast, is found by determining the maximum stress reached by the material (D. Pilkey Walter, 2005).

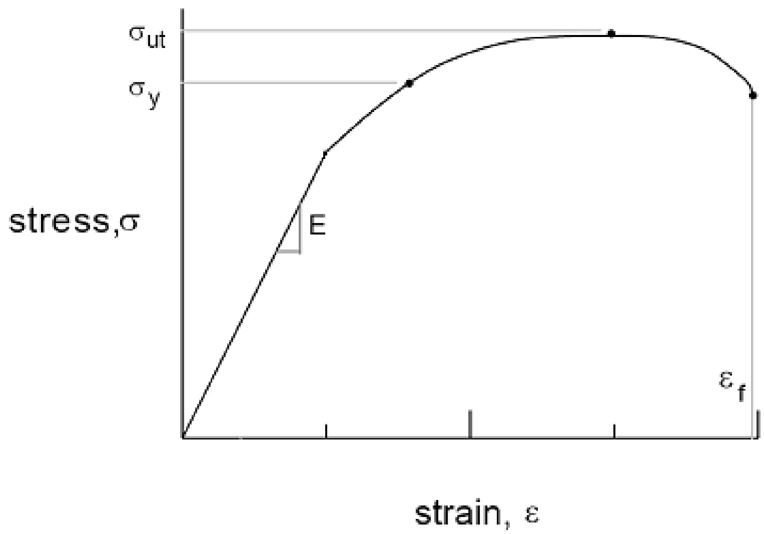


Figure 2.9: Stress-strain diagram

2.9 MEASURING INSTRUMENTATION

2.9.1 Tensile Machine

The machine used for this testing is Instron Tensile Machine. Samples will be clamped at each end before it is stretched until it ruptures. The crosshead speed was set during testing and must be uniform throughout the test.

The common data recorded by the machine are Young’s Modulus (MPa), Tensile strength (MPa) and extension at break or strain (%). All data and graph will be automatically recorded by the system. The machine can test wide range of materials from plastics to rubber and even thermoset composites.

Figure 2.10: Universal Tensile Machine

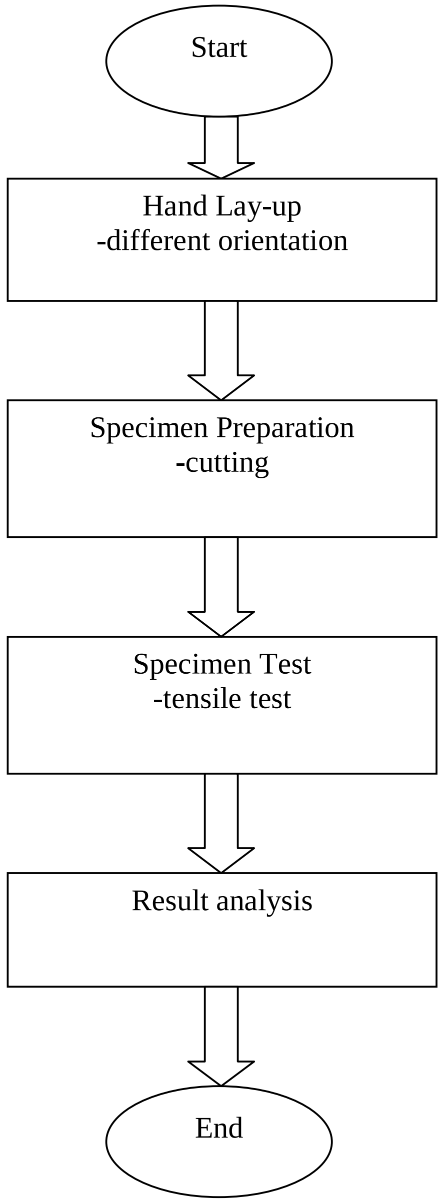
CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The overall project is represented by the project flow chart as shown in below. For this chapter, methodology is mainly about the explanation of the progress in this project. Besides that, this chapter will also show the overview of the project and the progress from the beginning until the end of the project.

3.2 GENERAL EXPERIMENT PROCEDURE



3.3 MATERIALS

The fibreglass is made from chopped strand mat (csm) fibre type. Tools and materials that are needed in preparing the fibreglass reinforced composite are;

i. Fibreglass (chopped strand mat)
ii. Thermosetting resin (polyester type)
iii. Hardener (react as accelerator)
iv. Roller
v. Zinc (mould)
vi. Safety tools (eye protection, mask)

3.4 MOULD PREPARATION

The mould is used for the hand lay-up process to take place. The type of mold used is open mold. The mould is prepared from the zinc.

The dimension of the mould are:

i. Length, L=210 mm
ii. Width, w= 110 mm
iii. Thickness, t= 5 mm

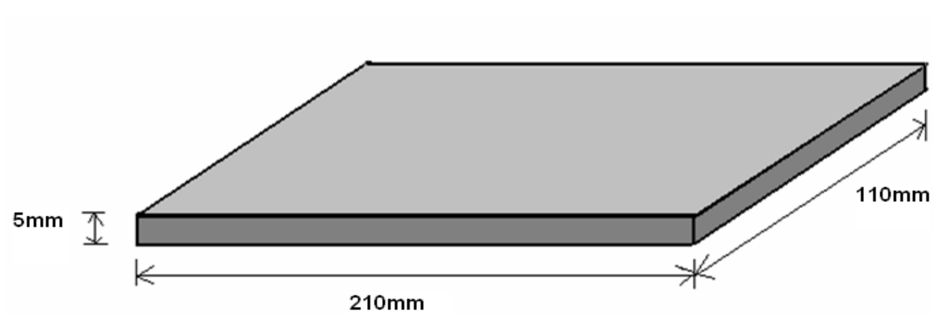


Figure 3.1: Open Mould

3.5 EXPERIMENT DESIGN

3.5.1 Build Orientation

In this study, the mix proportion (length, volume, and combination way of fibres) and in each mix proportion, three type of fibre orientation were prepared that is 0 °, 90 °, and random were chosen as parameters.

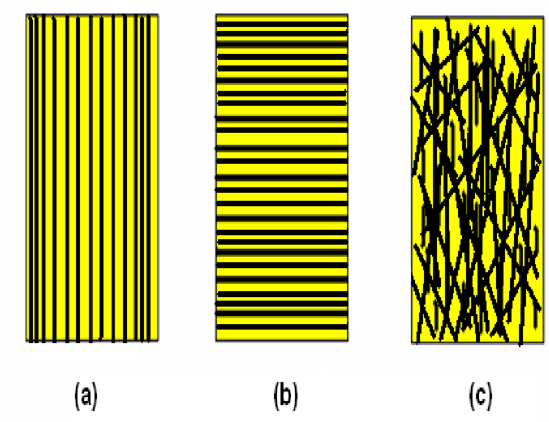


Figure 3.2: (a) 90 °, (b) 0 °, and (c) random

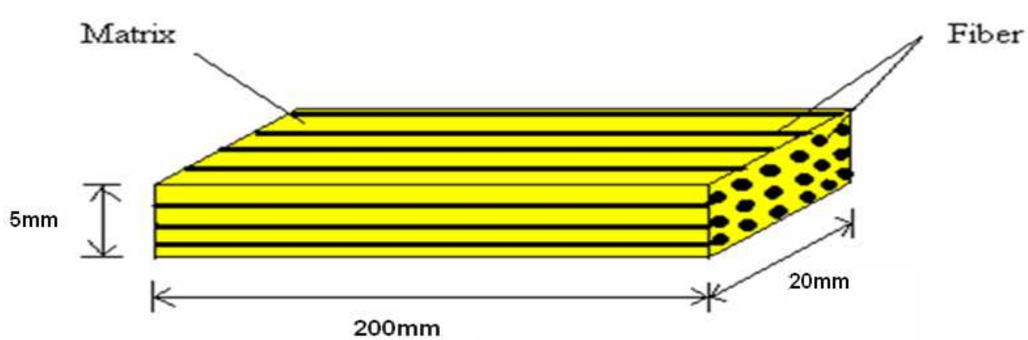


Figure 3.3: The size of specimen according to ASTM D3039 of 90° orientation

3.6 HAND LAY-UP PROCESS

Also called contact moulding. It is a production technique suitable for prototypes and low volume production of fibre composite material parts. The composite part will have a nice smooth surface on one side and a very rough one on the other. The fibres are manually placed into a one-sided of mould. A matrix of thermosetting resin is rolled onto the fibres using an hand roller. More layers can be added and, after drying, the composite part can be removed from the mould. Easy to control fibres orientation (R. Schmid Steven, 2001).

Furthermore, the process is very flexible as it can produce from very small, up to very large part of different kinds of geometry. The cycle time per part is very long, and only small series can be produced.

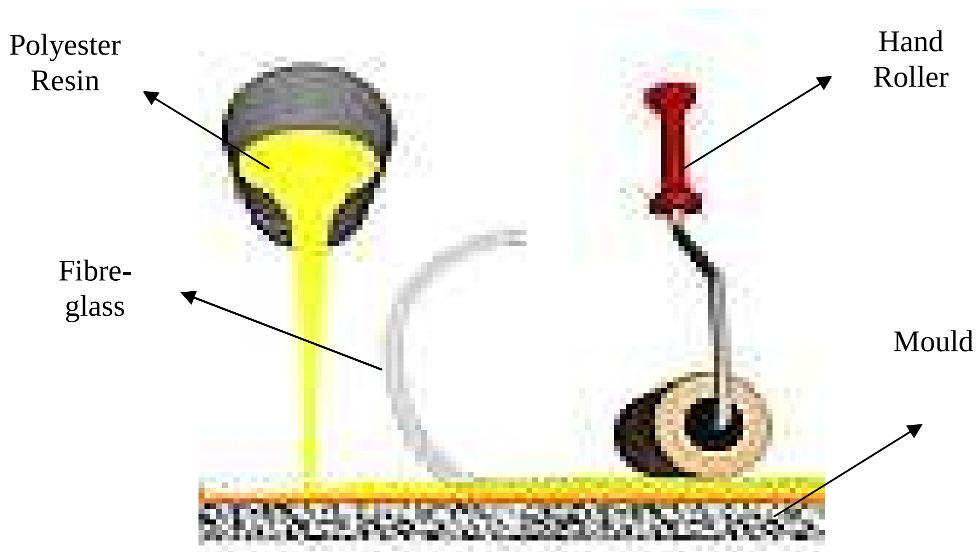


Figure 3.4: Hand lay-up

3.7 SPECIMEN PREPARATION

In preparing the specimens, the fibreglass is transformed to laminates, which is by using hand lay-up technique with thermosetting resin so in later it will become fibreglass reinforced composite. The fibreglass is first arranged in the mold one by one in three type of build orientation for each plate of laminate.

Resin is prepared with the hardener or accelerator and mixed together. The used of accelerator is necessary because without it, the resin does not cure properly. After adding the hardener, it should be left for some time so that the bubbles formed during stirring may die out. The amount of added hardener should be so high because it will affect the time of the solidifying of the matrix.

After mixing the resin with the hardener is complete, the laminate process take turns. Then, the resin is spread uniformly over the fibreglass and is rolled all over it by using a roller. This is because the resin need to be made sure that is blend perfectly in the mold and if not, the fibreglass will not solidify perfectly. The resin is used up till finish on all over the surface. When this finish, the laminate are left to be solidified by itself about 24 hours.

When all laminates are fully solidified, they then removed from the mold. Then, specimens that are need in experiment are cut from these laminate. T-jaw machine cutter will be used to cut the laminate to their specifications of sample needed.

Specifications of samples on the tensile test used are according to ASTM D3039.

3.8 TENSILE TEST

The specimens shape use in tensile test must be referred to the standard as done in ASTM D3039 so data that come out after the test are much preferable.

Progress involve during in the experiment are;

i. Specimens going to be tested are prepared.
ii. All information needed for tensile test machine programmed is put in. Load used is 50 kN, while thickness of specimens are varies.
iii. Specimens are clamped to the jaws and the test is run. Data that come out from the computer is logged in.
iv. The test is continued until all specimens are tested.

Table 3.1: Table of data for tensile test (laminates with 90°, 0º and random orientation of fibreglass used)

Num.	Max Displacement (mm)	Max Load (kN)	Max Stress (MPa)	Max Strain
1				
2				
3				
4				
5				

$$\text{Average maximum displacement} = \frac{\text{sum of maximum displacement}}{5} \qquad (3.1)$$

$$\text{Average maximum load} = \frac{\text{sum of maximum load}}{5} \qquad (3.2)$$

$$\text{Average maximum stress} = \frac{\text{sum of maximum stress}}{5} \quad (3.3)$$

$$\text{Average maximum strain} = \frac{\text{sum of maximum strain}}{5} \quad (3.4)$$

Table 3.2: Table of Young's Modulus, E (MPa) for 0º**,** random and 90º orientation of fibreglass

Num	**Young's Modulus, E (MPa)**		
	0º	**Random**	**90º**
1			
2			
3			
4			
5			
Average			

$$\text{Average Young's Modulus} = \frac{\text{sum of Young's Modulus}}{5} \quad (3.5)$$

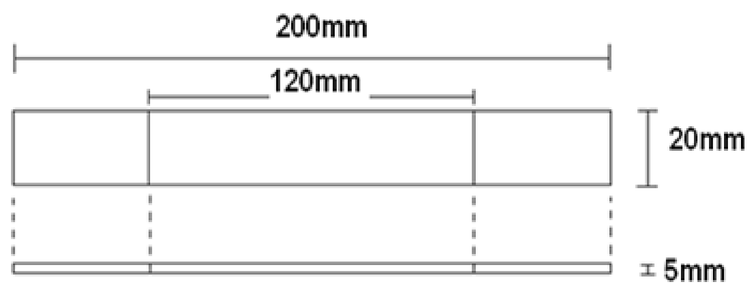


Figure 3.5: The dimension of tensile specimen according to ASTM D3039

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In order to obtain the mechanical properties of the fabricated composite laminates, tensile test was conducted. In this chapter, the details of test specimens for each category were discussed.

4.2 DATA

All data and graphs are generated by computer. The machine just need to be set up properly before run the test. Values that appear will then be taken.

4.3 TENSILE TEST

Details of specimens use for tensile test are as follow;
Material: Fibreglass (chopped strand mat laminates with polyester resin)
Samples: Follow on ASTM D3039
Samples are categorized to three type that is the orientation of fibreglass.

As mention, tensile test is for measuring the strength of the material. During the test, load is given, and fibreglass tends to elongate till it fracture suddenly. Values and graph is generated in the computer straight from this action. Figure 4.1 below shows the fracture of the sample.

Figure 4.1: Sample condition (break) after given load of 90° orientation of fibreglass

From the result value generated by the computer, we knew the value of displacement, load, stress, and strain achieved by each sample. Table 4.1 to 4.3 views the value generated by computer in tensile test.

Table 4.1: Result of tensile test (Fibreglass with 0º orientation)

Num.	**Max Displacement (mm)**	**Max Load (kN)**	**Max Stress (MPa)**	**Max Strain**
1	0.741	0.691	6.910	0.0062
2	0.764	0.786	7.860	0.0063
3	0.546	0.649	6.490	0.0046
4	0.431	0.349	3.490	0.0029
5	0.587	0.628	6.280	0.0049

Average maximum displacement = 0.6138 mm
Average maximum load = 0.6206 kN
Average maximum stress = 6.260 MPa
Average maximum strain = 0.0049

By using fibreglass with 0º orientation, the average maximum load is 0.6206 kN with the highest strength achieved is 0.786 kN. For maximum strain, the average value is 0.0049 which the average maximum displacement is 0.6138 mm. So, the sample only elongates just a little before tends to break. Figure 4.2 and 4.3 below is the load versus displacement graph and stress versus strain respectively, generated from the computer.

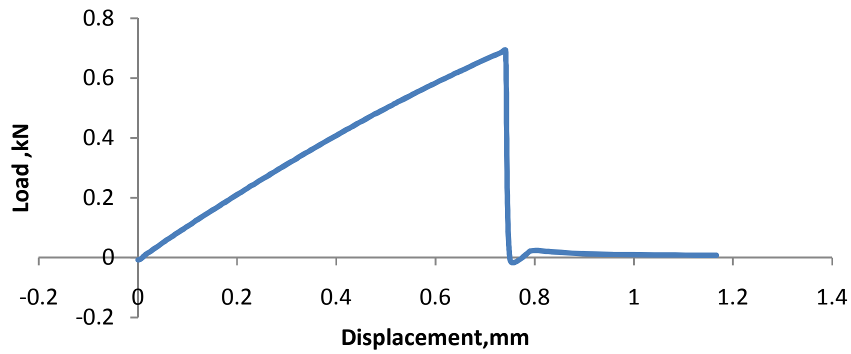


Figure 4.2: Graph of load versus displacement using fibreglass with 0º orientation

For this graph, the y-axis refers to load of tensile used to do the tension while the x-axis is the displacement of elongation of the sample till it break. The graph shows that the maximum load reached is about 0.69 kN and turn down straight to zero at around 0.74 mm of displacement.

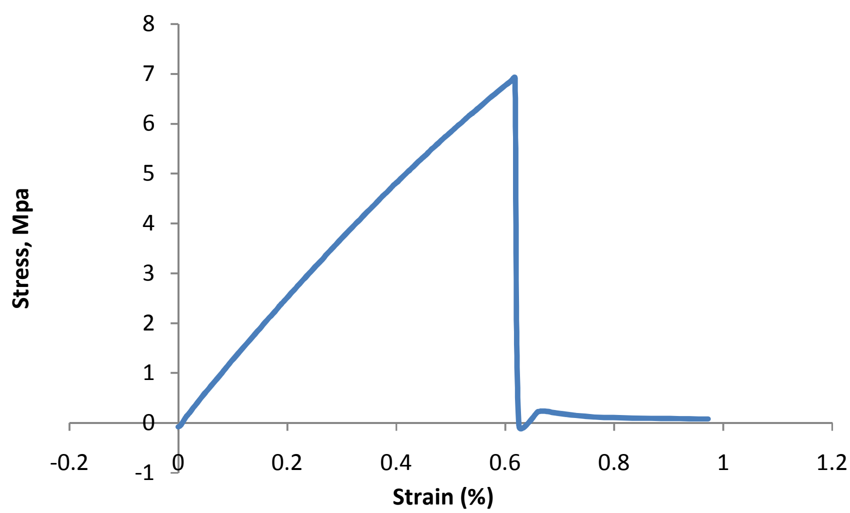


Figure 4.3: Graph of stress versus strain using fibreglass with 0º orientation

This is the stress versus strain graph for the sample by using fibreglass with 0º orientation. The peak of the graph is called ultimate tensile strength (UTS), which refers to maximum load given to pull the sample to its extension. First, the fibreglass will undergo elastic deformation, which is the stress is proportional to the strain. As the load is increases, stress is also increases and sample elongates more. At some level, it we can see here that the graph is suddenly falls to zero. Here, before it reach the peak, the specimen at some level first goes into plastic deformation. Stress is increase and fibreglass elongates till the maximum strength occurred. After that, the graph falls down to zero, means the sample does not go into necking deformation, instead it goes straight to fracture.

Table 4.2: Result of tensile test (Fibreglass with random orientation)

Num.	Max Displacement (mm)	Max Load (kN)	Max Stress (MPa)	Max Strain
1	2.491	1.467	14.67	0.0207
2	2.504	1.572	15.72	0.0208
3	2.128	1.374	13.74	0.0177
4	1.967	0.949	9.490	0.0163
5	2.116	1.095	10.95	0.0176

Average maximum displacement = 2.2412 mm
Average maximum load = 1.2914 kN
Average maximum stress = 12.91 MPa
Average maximum strain = 0.0186

For sample fibreglass with random orientation, all samples show an increase in maximum load volume. Four of them have more than 1 kN load of strength. The values also show that the more load given, the more stress is applied to the sample. Figure 4.4 and 4.5 below is the load versus displacement graph and stress versus strain respectively, generated from the computer.

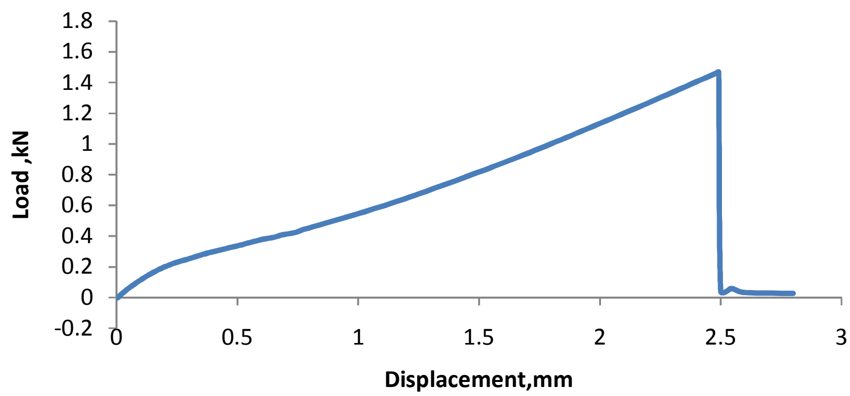


Figure 4.4: Graph of load versus displacement using fibreglass with random orientation

For figure 4.4, this graph is on specimens fibreglass with random orientation. The maximum load is higher than the previous load discussed, but still has a same pattern of graph. As can be see, the graph also falls down to zero as it reaches the peak of tensile strength.

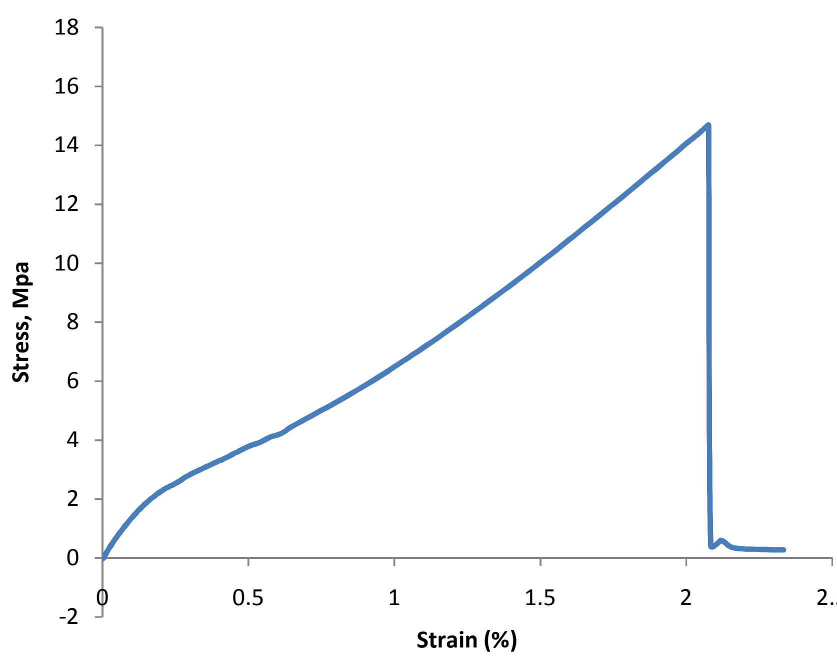


Figure 4.5: Graph of stress versus strain using fibreglass with random orientation

As for stress versus strain graph, it also shows that the fibreglass turns to fracture without having necking deformation. The stress is around 14 MPa and the strain is near 0.02.

Table 4.3: Result of tensile test (Fibreglass with 90º orientation)

Num.	Max Displacement (mm)	Max Load (kN)	Max Stress (MPa)	Max Strain
1	2.724	3.406	34.06	0.0227
2	2.598	3.324	33.24	0.0216
3	2.521	2.945	29.45	0.0210
4	2.462	2.763	27.63	0.0205
5	2.713	3.073	30.73	0.0226

Average maximum displacement = 2.6036 mm
Average maximum load = 3.101 kN
Average maximum stress = 31.02 MPa
Average maximum strain = 0.0216

For samples fibreglass with 90º orientation, there are more increases values in maximum strength of material. Only two sample give load lower than 3 kN. These values also can be understand that more load of tension is given to pull the sample, the longer of displacement take place, and the higher the stress is become. Figure 4.6 and 4.7 below is the load versus displacement graph and stress versus strain respectively, generated from the computer.

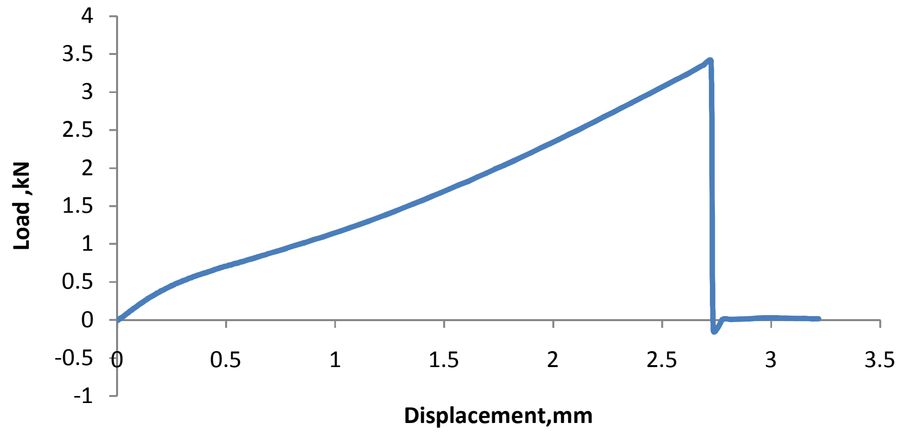


Figure 4.6: Graph of load versus displacement using fibreglass with 90º orientation

Here is the graph of load versus strain using specimens fibreglass with 90º orientation. The pattern of the graph is also same with two graphs. Here, plastic deformation can be see more clearly as yield stress take place at around 3 kN. Necking deformation also does not occurred in this graph.

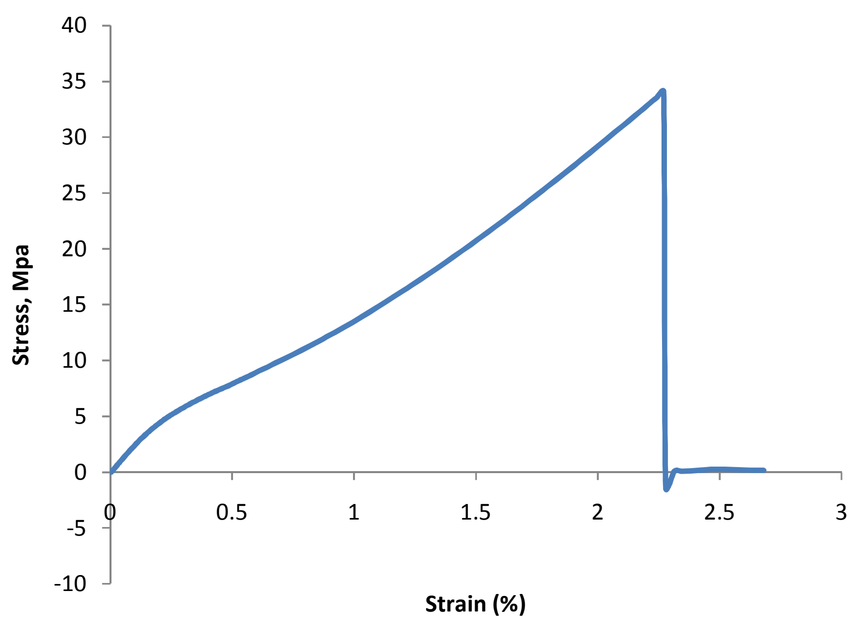


Figure 4.7: Graph of stress versus strain using fibreglass with 90º orientation

For the stress versus strain graph, it shows that plastic deformation is taking place, which the fibreglass stress is no more proportional to the strain. As load is given exceed the maximum stress, the specimen goes straight to fracture.

When refer to all graph of stress strain obtained, it shows that the entire graph falling straight down when it reach the peak. It does not turn into necking deformation; instead it acts like a brittle material. The graph just falls down straight away, means the fibreglass is totally break into two piece without necking. This is proved by the test, where fibreglass specimen does not have any necking deformation. Figure 4.8 is a sample of fibreglass that fractures (R. Naslaln, 2005).

Figure 4.8: A piece of damaged specimen (no necking occurred)

Table 4.4: Table of Young's Modulus, E (MPa) for 0^o**,** random and 90^o orientation

Num	**Young's Modulus, E (MPa)**		
	0^o orientation	**Random orientation**	**90^o orientation**
1	11.145	7.087	15.004
2	12.476	7.558	15.389
3	14.108	7.763	14.024
4	12.034	5.822	13.478
5	12.816	6.222	13.597
Average	12.516	6.890	14.298

From the observation, it shows that the Young's Modulus of the composite varied from one sample to another. The 90° orientation sample shows the highest Young's Modulus compared to other samples. Greater value of Young's Modulus refers to a tougher material. The existent of the fibreglass in the sample make the composite becomes tough. The combination of polyester and fibreglass based on 90^o orientation make them hold the structure before the molecules of polyester slip pass one another. Besides that, the covalent bonding in the composite help the sample from setting slip easily when the tensile force is applied. High strength is needed to break the fibre that holds the original material from breaking (Nicholas A. Warrior, 2009). The 90° orientation of fibre had higher strain rate compare to 0^o and random orientation thus resulting in high value of Young's Modulus. This is because of the higher interaction between the matrix and fibres. This situation has change the modulus of elasticity in term of the strain rate of the composite.

Table 4.5 below is the overall data for average value taken from the tensile test

Table 4.5: Table of all average value in tensile test

Average	**Fibreglass orientation**		
	0º	**Random**	**90º**
Average max. displacement (mm)	0.6138	2.2412	2.6036
Average max. load (kN)	0.6206	1.2914	3.101
Average max. stress (MPa)	6.260	12.91	31.02
Average max. strain	0.0049	0.0186	0.0216
Average Young's Modulus (MPa)	12.516	6.890	14.298

From the test, it observed that 90º orientation of fiberglass is the highest in tensile strength from other orientation. This is because the arrangement of fibreglass with 90º orientation to the loaded given is parallel, which means more load needed to create tension, till it break the sample compare to the 0° orientation and random orientation of fiberglass. The 0° orientation of fiberglass is perpendicular to the load given, which means lower load is needed to break the samples. So, for the composite with 0° orientation of fibreglass tends to break easily compare to other (Paul Gramann, 2003). The tensile strength of random orientation is lower than 90º orientation because of the random orientation cannot hold the structures of the composite as well as the 90º orientation. This is also because the increasing usage of fibreglass in the 90º compare to the random orientation. As the fiberglass increased, the higher the bonding between the fibre and matrix will become, thus resulting in high strength.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

The objective of this project is to study on the mechanical properties of reinforced plastic and fibreglass specifically.

From observation, and graph obtained, it shows that fibreglass have high strength but still acts like a brittle material. This is proved by stress versus strain graph which no necking deformation occurred. The values of maximum strain between each three group are also not quite varies with each other, which also means it goes straight to fracture without necking.

Hence, it can be conclude that by arrange the fibreglass properly, the strength of laminate (specimen) becomes stronger. The various value obtained on each sample depends on the strength bonding between fibre and resin matrix, because load is transmitted through the fibre matrix interface.

The fibreglass also have superior mechanical properties which is better tensile strength and toughness.

5.2 RECOMMENDATIONS FOR THE FUTURE RESEARCH

For a better strength, the use of adhesion at the interface (resin) can be improved by special treatments, such as coatings and coupling agents. Fibreglass, for example , are treated with a chemical called silane (a silicon hybride), for improved wetting and bonding between the fibre and matrix. Another way is like using other type of resin such as epoxy resin which has better properties than polyester resin.

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Appendix A1: Project Gantt Chart for FYP I

Project Progress		W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14
1) Get the project title and arrange discussion time with supervisor	Planning														
	Actual														
2) Built the basic knowledge about the project	Planning														
	Actual														
3) Do research and collect the information from various resources	Planning														
	Actual														
4) State the objective, scope and importance of the study	Planning														
	Actual														
5) Review study of composites journal and thesis	Planning														
	Actual														
6) Study of composites and its application	Planning														
	Actual														
7) Study of fibreglass and its applications	Planning														
	Actual														
8) Design the step of preparation of the project	Planning														
	Actual														
9) State the overview of the experiment's procedures	Planning														
	Actual														
10) Provide the expected result based on previous research	Planning														
	Actual														
11) Submit draft report and log book for final year project 1	Planning														
	Actual														
12) Final year project 1 presentation	Planning														
	Actual														

Planning

Actual

Appendix A2: Project Gantt Chart for FYP II

Project Progress		W 15	W 16	W 17	W 18	W 19	W 20	W 21	W 22	W 23	W 24	W 25	W 26	W 27	W 28
1) Analyze the information	Planning	■	■	■											
	Actual	■	■	■											
2) Apply mechanical test	Planning	■	■	■	■	■	■	■	■						
	Actual				■	■	■	■	■	■					
3) Analyze data and records	Planning							■	■	■	■				
	Actual							■	■	■	■				
4) Result and discussion	Planning								■	■					
	Actual									■	■				
5) Conclusion	Planning									■	■				
	Actual										■	■			
6) Report writing	Planning									■	■	■			
	Actual									■	■	■	■	■	
7) Presentation with supervisor	Planning												■		
	Actual												■		
8) Final Presentation	Planning													■	
	Actual													■	
9) Submit report	Planning														■
	Actual														■
10) Submit Final Report	Planning														■
	Actual														■

Planning

Actual

Appendix B: A sample of fracture specimen after given tensile test for (a) 90 °, (b) random and (c) 0 ° orientation