TENSILE PROPERTIES OF COMPOSITE LAMINATES DUE TO FUEL ATTACK

by

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ABSTRACT

The main purpose of this study is to investigate the effects of kerosene, biofuel, distilled water and room temperature condition on the moisture behavior and mechanical properties of the E-glass reinforced composite. A laminate composite from the E-glass composite material is fabricated that consist from two type of resins which are polyester-based resin and epoxy-based resin. A variety method has been conducting which are the traditional hand layup, resin infusion (RI) and vacuum resin transfer molding. The fiber content for each methods is calculated by using density method and resin burn-off method. The specimens is immersed in the three type of solution and the accuracy of Fick's Law on moisture diffusion is studied. All specimen were left until it is fully saturated respective to its solution. A tensile test was performed subsequently by using the Universal Tensile Machine (Instron) (UTM). The data obtain from the mechanical test were plotted in a graphical approach by using the tensile stress versus strain graph and average tensile stress bar chart. The data obtained were studied and a comparison of data are being made between both type of resin and also between the three different solutions. It was found that there are no significant change in tensile stress and tensile modulus for all the specimen being immersed in kerosene, biofuel and distilled water and in room condition hence this E-glass fiber reinforced composite can be used in manufacturing the fuel tank structure both in marine and aerospace application.

SIFAT TEGANGAN LAMINA KOMPOSIT AKIBAT SERANGAN BAHAN API

ABSTRAK

Tujuan utama kajian ini ialah untuk mengkaji kesan minyak tanah, biodiesel, air suling dan keadaan suhu bilik terhadap tingkah laku penyerapan komposit dan juga sifat mekanikal komposit yang diperkukuhkan dengan E-glass. Komposit lamina ini dibuat melalui bahan E-glass yang terdiri daripada dua jenis resin iaitu polyester dan epoxy resin. Pelbagai cara telah dijalankan termasuk lah tradisional “Hand-Layup”, “Resin Infusion” dan juga “Vacuum Resin Transfer Molding”. Kandungan fiber di dalam setiap komposit telah dikara menggunakan kaedah ketumpatan dan juga pembakaran resin. Kesemua sampel telah direndamkan di dalam tiga jenis kandungan dan ketepatan “Fick’s Law” telah dikaji. Kesemua sampel telah ditinggalkan sehingga semuanya benar-benar tepu. Ujian ketegangan telah dijalankan dengan menggunakan Instron Tensile Machine (UTM). Semua data dan maklumat daripada ujian mekanikal telah diplot kan di dalam graf yang terdiri daripada “stress versus strain”, dan carta bar “ average tensile stress”. Data yang didapati telah dikaji dan perbandingan mengenai kedua-dua resin yang direndam di dalam tiga keadaan telah dibuat. Didapati bahawa kesemua specimen yang telah direndam di dalam minyak tanah, biofuel, air suling dan dalam keadaan suhu bilik tidak mempunyai perubahan yang ketara terhadap ‘tensile stress’ dan ‘tensil modulus’ dan oleh itu komposit yang diperkukuhkan dengan E-glass ini sesuai digunakan untuk membuat tangki minyak bagi aplikasi marin dan aeroangkasa.

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The completion of this industrial training could not have been possible without the participation and involvement of so many people. Their contribution is highly appreciated and gratefully acknowledged.

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

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LIST OF ABBREVIATIONS

RI	Resin Infusion
VRTM	Vacuum-assisted Resin Transfer Molding
UTM	Universal Testing Machine

CHAPTER 1

INTRODUCTION

1.1 General overview of composite

The development of composite in related design as well as in manufacturing technologies is one of the most advance in the history of material. In cannot be denied that the enhancement in many form of technological development is greatly dependent in the field of material. There are thousands of material available for use in engineering application. Within this type of classification, composites are mainly used in the field of diverse range application such as in aircraft, boats, automobiles, ships, sporting goods and also civil transportation. Composite can be refer to materials containing strong fibers embedded in a weaker material or matrix. In a short word, composite are a grouped of constituent material being combined together to produce a significantly different physical and chemical properties. But this kind of combination is likely will exhibit a unique properties such as resistance to wear, corrosion and high strength. It is being assume that for a coming years, this consumption of composite will continue to grow with the emerging of developing new technology in computer hardware, large structures, biomedical services and also offshore platform.

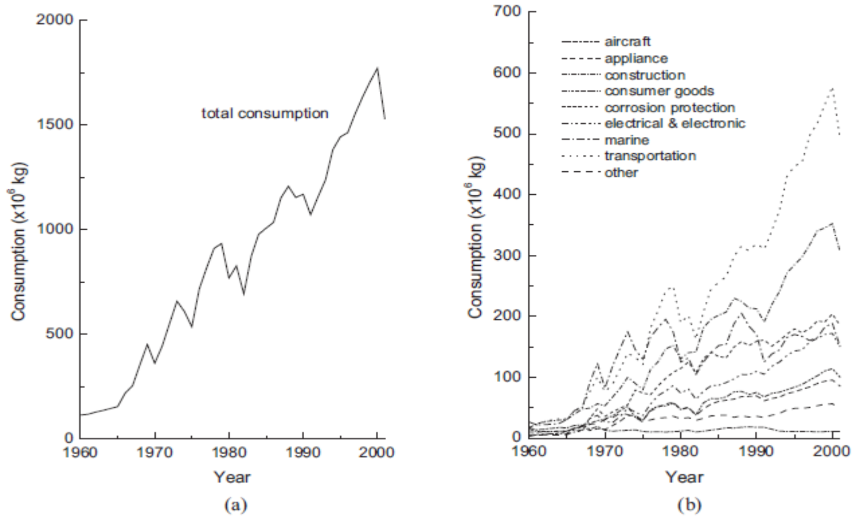


Figure1. 1:Growth in the (a) total use and (b) use by individual market sectors over the United State [1]

1.2 Classification of the composite

In using composite in structural design, one must acknowledge the two different types of composite which are the fibrous composite and particulate composites. Example of fibrous composites are carbon-fibre-reinforced plastic (CFRP) and glass-fibre-reinforced plastic (GFRP). A particulate composite in the other hand is a metal matrix composite (MMC) which usually a combination of a non-metallic particles in a metallic matrix.

Both composite is well-known for its stiffness and strength but the most important difference between those two relates to its directionality of properties. Fibrous composites are anisotropic but particulate/conventional composites are isotropic which mean that their properties (strength, stiffness) are the same in all direction compared to that of a fibrous composites.

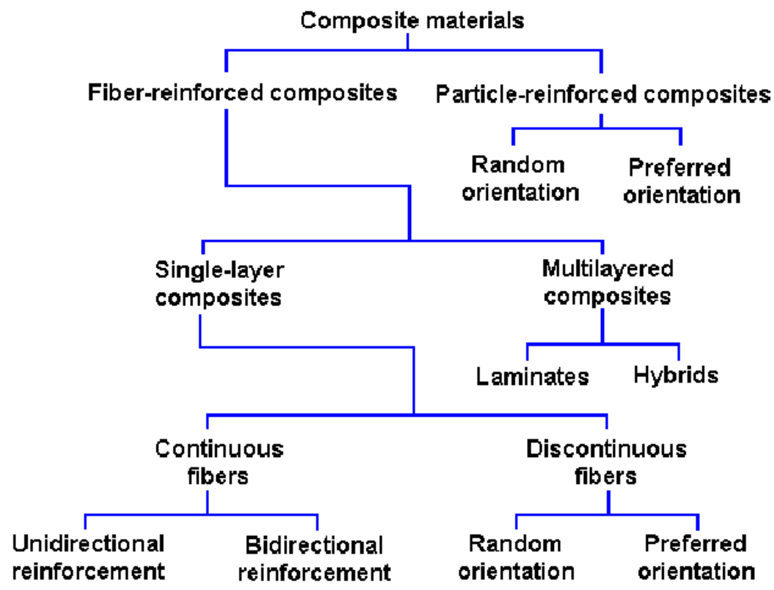


Figure1. 2: Classification of the composite materials

1.3 Composite in aerospace application

From over a decade, this use of composite is not a new thing. A brief history over the past years has indicate that the use of composite in aerospace construction. For an example, in 1938, the fighter aircraft Morane 406 (FRA) had sandwich panels made of plywood core and light alloy skin. The glass/resin has also been used since 1950 and with the combination of the honeycombs, this composite enables the manufacture of fairings with complex shapes.

Because of its ability in performing into complex shapes, composite material is widely used in aerospace component, which not only reduces the number of parts making up a component but also reduces the need for fasteners and joints which eventually will less the potential crack-initiation site at the joint.

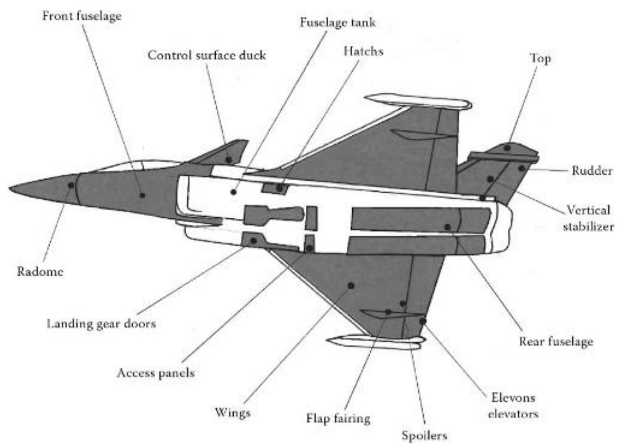


Figure1. 3: Composite usage in Fighter aircraft Rafale, Dassault Aviation (FRA) (Source: Composite Materials and Aerospace Construction)

As many part of the aircraft used composite material for their structure, the wing itself is mainly used composite especially for the fuel tank structure that is being used in the "wet wing" type. This basically used integral tanks which situated inside the aircraft structure that commonly used in larger aircraft like Airbus 340.

Figure1. 4: The different tanks and their location for Airbus A340

1.4 Advantages and disadvantages of composite

As composite is the combination of two distinct material to have a greater physical properties, thus it present a huge advantage. Some of the advantages of the composite will be stated as below:

- Reduced weight and formability as manufacturer and assembly part are simplified as metallic counterparts is reduced (joint/fastener) thus reduced the cost.
- Can produce complex part thus increase smooth aerodynamic profiles
- Have low thermal conductivity and low coefficient of thermal expansion.
- High strength to weight ratio
- Offer a high resistance to corrosion and good resistance to fatigue.

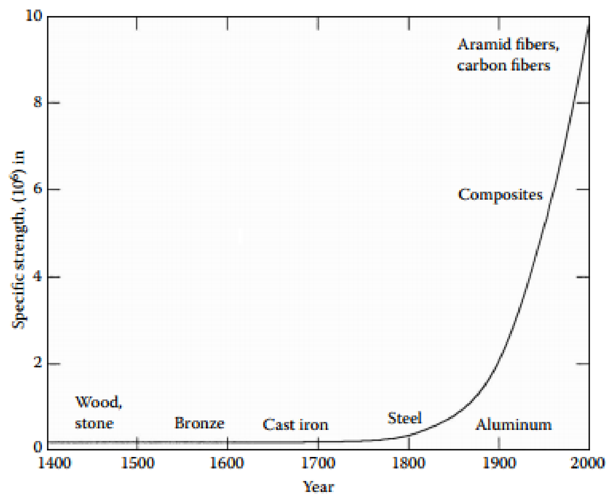


Figure1. 5: Specific strength of composite material compared to other material

Even it is being compared that composite gives a lot of benefits, but there are also drawbacks and limitations in using them. One of the major concern is the raw material in fabricating them is high in cost which is a critical issue. As the demand of composite is increasing, thus manufacturer wants the cost to be slightly lower compare earlier development of composite. But, the advancement of fabrication and processing technique will slightly reduced the costs in the future.

The repairing of the composite is also complicated and not a simple process as sometimes the cracks cannot be detected in simple process. Moreover, composites do not have a high combination of strength and fracture toughness compared to metal and the ductility is better compared to metal.

1.5 Motivation and Problem Statements

Composite is now widely used for aircraft manufacturing in many components or part of the aircraft. Due to its weight reduction, easy to assemble and high impact resistance, there has been a significant increase in using fiberglass/E-glass composites in making the fuel tank. However, a deep research and understanding about the reaction between the composite materials used as a fuel tank and in marine application with the fuel attack over time must be taken into account that lead into the changing of tensile mechanical properties of the composite. However for over a year, the experiments of composite is only covered the exposure of the composite material against humid air. There are only a few data available on the full immersion of composite into the fluid/fuel immersion. A recent experiment that has been conducted covered up only in the determination of moisture content of the graphite-epoxy composite and E-glass-polyester composite that is submerged in different liquids.

Hence, this will leave to an abundant of unanswered question such as the changes of mechanical, thermal, chemical and physical properties of the composite.

1.6 Objectives of Research

The research work described in this thesis is performed based on the following objectives:

(i) To manufacture the E-glass composite material by using the resin infusion (RI) and vacuum resin transfer molding (VRTM).

(ii) To determine the moisture content of the composite in the function of time and temperature due to the immersion in different type of fuel.

(iii) To conduct and perform a tensile mechanical test on the composite laminate.

(iv) To evaluate the performance of composite due to fuel attack by tensile mechanical testing.

1.7 Thesis Layout

This thesis comprises of 5 chapter. Chapter 1 will have a general introduction of composite in industry and also the classification of composite in general. Some of the advantages and drawbacks of composite will also be discussed here as well as the usage of composite in general application and also in aerospace industry. Next, this chapter also will be discussing about the behaviour and mechanical properties of composite with its reaction towards fire together with the fire incident regarding the usage of composite in aircraft manufacturing. The problem, motivation of doing the research and also objectives are clearly defined at the end of this chapter.

Chapter 2 explains all the literature such as journals, papers and articles that is related to this research. It will be deeply focusing on the characteristic, mechanical properties of the composite material, and also the resin used in this experiment and testing.

Chapter 3 demonstrate all methodology and step by step procedure that is being used in this research. It comprise all the available methods that have been used in fabricating and manufacturing the composites. This section provides detail information about material being used throughout the process of fabrication, moisture uptake and mechanical testing that is being used in this research.

Chapter 4 reveal and analyze all the results from the testing that has been carried out. The data and information provided in this chapter is discussing about the trend of moisture uptake of the E-glass composite in different type of fluid immersion, stress strain behaviour, ultimate stress, Young's Modulus and the composite reaction towards fire.

As a closing, Chapter 5 summarize all the information that has been point out throughout this research with a acutely focusing on the number of improvements that can be carried out to enhance the availability and sustainability of the research. All the suggestions and recommendations in using E-glass/ fibreglass as a fuel tank structure or other part component in aircraft is being reviewed to make sure the method is feasible in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Usage of composite

Recent years has shown that the uses of composite in many areas such as the aerospace, maritime, civil and medical filed has increase significantly in a positive manner. Over this period consumption has increased about 30 times, and the growth rate is expected to continue. The significant increase in composite is being showed clearly by A.P. Mouritz and A.G. Gibson in '*Fire Properties of Polymer Composite Material'*, which stated that The greatest increases are occurring in the transport and construction markets, although the use of composites is also substantial in the corrosion protection (eg. piping), marine, and electrical/electronic markets as shown in Fig. 1.2[1].

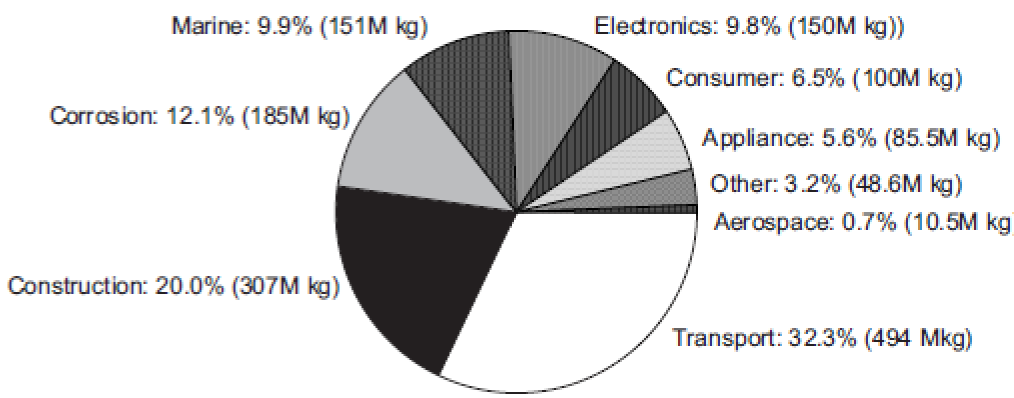


Figure 2. 1: Use of composite materials by different market segments in the United States in 2001 [1]

2.2 Moisture Absorption of E-glass Composite

The high performance of composite can be deniable and can give many advantages in humankind. But, however there is some concern regarding its mechanical properties of such materials as they were exposed in moisture for a long periods of time especially for marine and fuel tank use which is in water and fuel respectively. Therefore, in order to fully utilize the potential of these material in manufacturing application, the moisture uptake respect to the time must be known.

After several research and finding, it can be stated that the amount of moisture uptake of a composites depends on several factors such as the composite void content, the type of curing agent, the temperature and percentage of humidity. J.L Thomason from his paper stated that the rate of water absorption in glass fibre-reinforced epoxy matrix composites is primarily dependent on the void content[2]. It dependent is so strong that the presence of only 1% voids content in the composite laminate can more than double the amount of water absorption process. As composite needed a curing agent like polyester or epoxy resin, thus this type of different matrix system also plays an important role of water uptake [2].

This effect of water uptake does not involve only the laminate composite but also other type of composite in general. J. M. Ryan, R, Adams and S. G. R. Brown from School of Engineering, Swansea University stated that as composite is immersed in fluid with the combined of operating temperature, it will significantly weakens the mechanical properties of the materials[3]. The moisture uptake is stated to be agreed with the

Ficks's second law as the result reveal that the strength of the composite laminate from 977-2-HTA 12H 34% carbon pre-preg was seen to decrease by 50% strength reduction as compared to oven dry. The in-plane shear strength and modulus was also seen to be decreased to a maximum 20% and 10% respectively due to the high content of moisture.

Regardless of the negative effects on the composite due to moisture exposure, there are also some hypothesis regarding the respective case. According to Beckry Abdel-Magid, Saeed Ziaee, Katrina Gass and Marcus Schneider [4], the effect of properties of E-glass/epoxy is dependent on the duration of the conditioning environment. The paper stated that at shorter duration of applied stress and moisture conditioning at room temperature, a slight increase in strength and a slight decreased in modulus were observed. But at longer condition, a noticeable reduction in strength and strain-to-failure were observed[4].

There are some experimental testing that has been conducted to observe the behavior of the composite with the amount of moisture uptake for the past year. One of the experiments being conducted is the moisture absorption of Polyester-E Glass composites by Alfred C. Loos, George S.Springer, Barbara A, Sanders and Randy W.Tung. The polyester-E glass composite were immersed in distilled water, saturated salt water, No.2 diesel fuel, jet A fuel, synthetic aviation lubricant, gasoline and in exposed humid air [5].

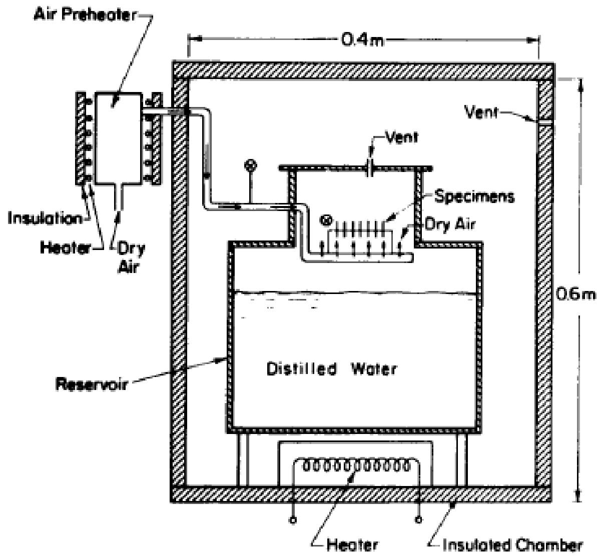


Figure 2. 2:Schematic of apparatus of laminate exposed to humid air (Source from reference [5]

It has been observed that the weight of each material changes with the function of time and temperature. The result presented that the weight change depends on the material, temperature, and the composition of the environment (relative humidity of the air or the type of liquid used) [5].

It also has been reported that all the samples in the experimental testing obeys the Fickian diffusion model which requires the result to be plotted as weight gain (as a percentage of dry weight) versus square root of time [2] [3] [6] and [5].

2.2.1 Moisture diffusion calculation

Moisture diffusion can gives different effect to the composite itself. The defect will slightly depending on the time, environmental conditions and type of fluid. The longer the time taken in this fluid, the more severe the deterioration of the matrix as compared to the previous paper and investigation. The weight of the specimen are being calculated by using the formula:

$$M = M(t) = \frac{Weight\ of\ moist\ material, m(t) - Weight\ of\ dry\ material, m_{dry}}{Weight\ of\ dry\ material, m_{dry}} x\ 100 \quad (2.1)$$

Where;

$m_{dry} = The\ initial\ mass\ of\ the\ specimen$

$m(t) = The\ mass\ of\ the\ specimen\ after\ immersion\ for\ time\ t$

$M(t) = The\ percent\ moisture\ content\ of\ the\ specimen\ as\ a\ function\ of\ time$

Moisture absorption is characterized by the migration of molecules down the concentration gradient which occurs through diffusion. The moisture absorption is then being plotted in a graphical approach that obeys the Fickian diffusion estimation.

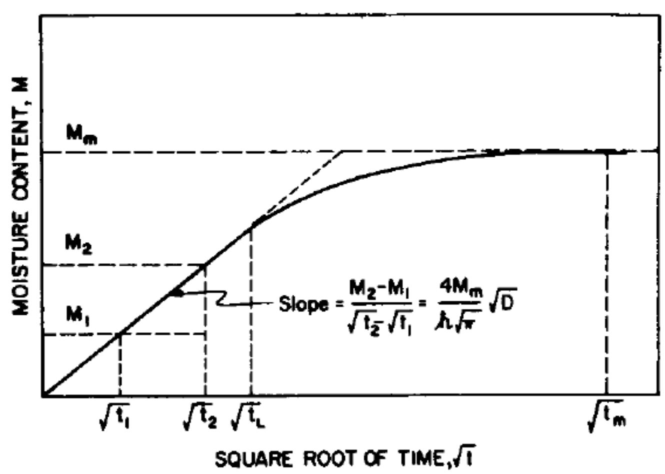


Figure 2. 3: Illustration of the change of moisture content over the square root of time [6].

For a relatively large and thin composite laminate, moisture diffusion primarily will occur through the laminate faces and only a small fraction takes place through the thin edges. The concentration difference is the main driving force for diffusion at a given temperature. According to Fick's Second Law, for a constant diffusivity D along the thickness direction z, the moisture concentration C is [7]:

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial t^2} \quad (2.2)$$

$$C(t) = \lim_{\Delta V \to 0} \frac{m_t(\Delta V) - m_d(\Delta V)}{m_d(\Delta V)} \quad (2.3)$$

The moisture uptake M is defined by:

$$M = M(t) = \frac{m_t - m_d}{m_d}\ x\ 100 \quad (2.4)$$

Normally, a plot of moisture uptake against square root time from a moisture experiment is made and the diffusion coefficient is calculated by the slope of the linear uptake region:

$$D = \frac{\pi}{16}\left[\frac{l}{M_\infty}\right]^2 \left[\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}}\right]^2 \quad (2.5)$$

Where:

$M_\infty = The\ moisture\ mass\ uptake\ at\ equilibrium$

$t = Time\ taken$

$L = Thickness\ of\ specimen$

2.3 Characteristic and Chemical Properties of Composite Material

Solid material can be divided into four categories which are polymers, metals, ceramics and carbon for this will gives the ability to create limitless number of new material. In this four categories, lies four categories of composites material depending on the type of matrix being used such as polymer matrix composite (PMCs), metal matrix composites (MMCs), ceramic matrix composites (CMCs) and carbon matrix composites (CMCs) [1]. But the most common usage of composite nowadays is the polymer matrix composite (PMCs).

2.3.1 Fiber Glass

In making the composite material, there will be a numerous type of fiber to be chosen. Some of them are glass fiber, carbon/graphite fiber, boron fiber, fiber based on silicon carbide, fiber based on alumina, aramid fiber/Kevlar, high density polyethylene fiber and basalt fiber. In this project, there will more detail on discussing the glass fiber itself with the uses of polyester and epoxy resin.

Glass fibers are used primarily to reinforced polymers. It is often used for secondary structure on aircraft such as fairings and radomes and also in marines application. In recent year, glass fiber also well known for its usage in manufacturing the fuel tank and also as structural materials in naval mine countermeasure surface ships. Several type of fiberglass are E-glass, that is made from borosilicate glass. But S-glass and S2-glass indicates a higher strength than E-glass. One of the advantages of E-glass is that it is much more cheaper than other composite material and does not conduct electricity. As glass fiber is well known for its high resistance to current flow, one paper by Monaj Singla and Vikas Chawla stated that the characteristics of glass fiber for both compressive and impact strength increase with the addition of fly-ash particles [8].

Fiber	Density g/cm^3 (pci)	Axial Modulus GPa (Msi)	Tensile Strength MPa (ksi)	Axial Coefficient of Thermal Expansion ppm/K (ppm/°F)	Axial Thermal Conductivity W/m·K
E-glass	2.6 (0.094)	70 (10)	2000 (300)	5 (2.8)	0.9
HS glass	2.5 (0.090)	83 (12)	4200 (650)	4.1 (2.3)	0.9
Aramid	1.4 (0.52)	124 (18)	3200 (500)	–5.2 (–2.9)	0.04
Boron	2.6 (0.094)	400 (58)	3600 (520)	4.5 (2.5)	—
SM carbon (PAN)	1.7 (0.061)	235 (34)	3200 (500)	–0.5 (–0.3)	9
UHM carbon (PAN)	1.9 (0.069)	590 (86)	3800 (550)	–1 (–0.6)	18
UHS carbon (PAN)	1.8 (0.065)	290 (42)	7000 (1000)	–1.5 (–0.8)	160
UHM carbon (pitch)	2.2 (0.079)	895 (130)	2200 (320)	–1.6 (–0.9)	640
UHK carbon (pitch)	2.2 (0.079)	830 (120)	2200 (320)	–1.6 (–0.9)	1100
SiC monofilament	3.0 (0.11)	400 (58)	3600 (520)	4.9 (2.7)	—
SiC multifilament	3.0 (0.11)	400 (58)	3100 (450)	—	—
Si–C–O	2.6 (0.094)	190 (28)	2900 (430)	3.9 (2.2)	1.4
Si–Ti–C–O	2.4 (0.087)	190 (27)	3300 (470)	3.1 (1.7)	—
Aluminum oxide	3.9 (0.14)	370 (54)	1900 (280)	7.9 (4.4)	—
High-density polyethylene	0.97 (0.035)	172 (25)	3000 (440)	—	—
Basalt	2.7 (0.099)	100 (15)	2900 (430)	5.5 (3.1)	1.7

Table 2. 1: Properties of Key Reinforcing Fibers [1].

2.3.2 Polyester Resin

Polyester resin is mainly used in marine industries by far for dingies, yachts and workboats. This type of resin usually from the unsaturated type. Unsaturated resin is a thermoset resin. Thermoset resin are the most diverse and widely used of all man-made materials. Polyester resin usually used in a low cost operation as it is inexpensive and fast processing. Some method that has being applied by using a polyester resin include wet hand layup, vacuum resin transfer molding (VRTM) injection molding, filament winding pultrusion and autoclaving.

Polyester are formed by the condensation polymerization of a diacid and a dialcohol (a diacid means two organic groups are present in a molecule, and a dialcohol has two alcohol groups in a molecule) A typical reaction is shown below in which maleic acid is made to react with the ethylene glycol to form polyester. The acid group (O=C–OH) on one end of the diacid reacts with the alcohol group (CH2OH) on one end of the diol to form a bond linking the two molecules and to give out water as a byproduct.

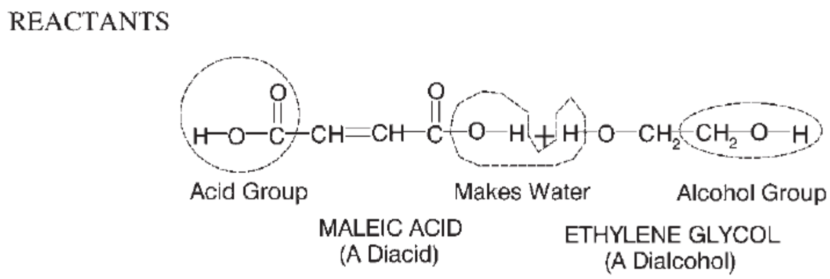


Figure 2. 4: Reaction of maleic acid with glycol molecule

The linking group which is formed is called an *ester* (C–O–C=O). This step is called a condensation reaction. The resulting product still has another acid group on one end and another alcohol group on the other. Both of these ends are still capable of undergoing further condensation reactions and then to repeat again and again. Therefore, with sufficient reactant materials, chains of alternating acid and alcohol groups will form and will have regularly repeated units as shown in the polymerization step below [9]:

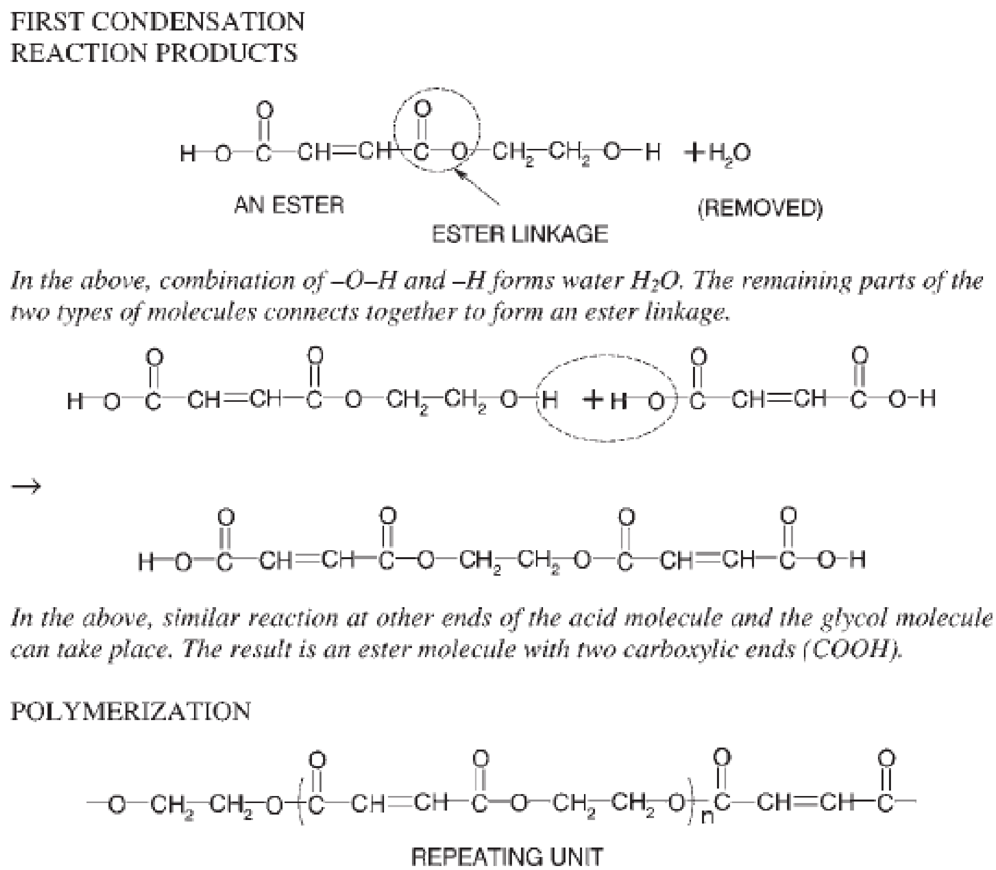


Figure 2. 5: Condensation polymerization of a polyester resin (Source from reference [9]

Activation of a polyester can occur whenever the is an addition of initiators, raising of temperature or strong mixing activities. Some efforts are made up to make prepregs using polyester but most common use are in wet. These include wet hand-lay-up, wet filament winding and liquid composite molding [9]. There is a thing called pot life where it determine the duration of the resin in the pot without going bad. Different applications may require a different pot lives. The pot life can be adjusted using modified amount of catalyst, inhibitors or accelerator.

2.3.3 Epoxy Resin

The Epoxy resin also one of the common used in polymer matrix composites. It is one of the families in thermoset which do not give off reaction products when they cure and so have low cure shrinkage [8]. Epoxies has been used extensively as it has excellent adhesion, high strength, good corrosion resistance, low shrinkage (as compared to polyester) and processing versatility.

Epoxies are characterized by the presence of an epoxy group which are the three-membered ring with two carbon and an oxygen.

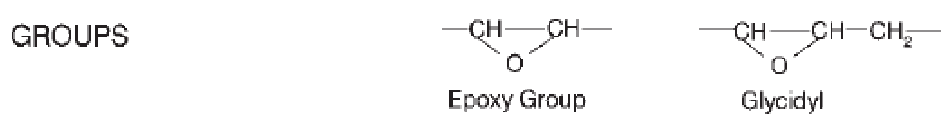


Figure 2. 6: Member of epoxy

The reaction of epoxies is roughly the same with those carbon-carbon double bond in polyester although the reactions are quite different.

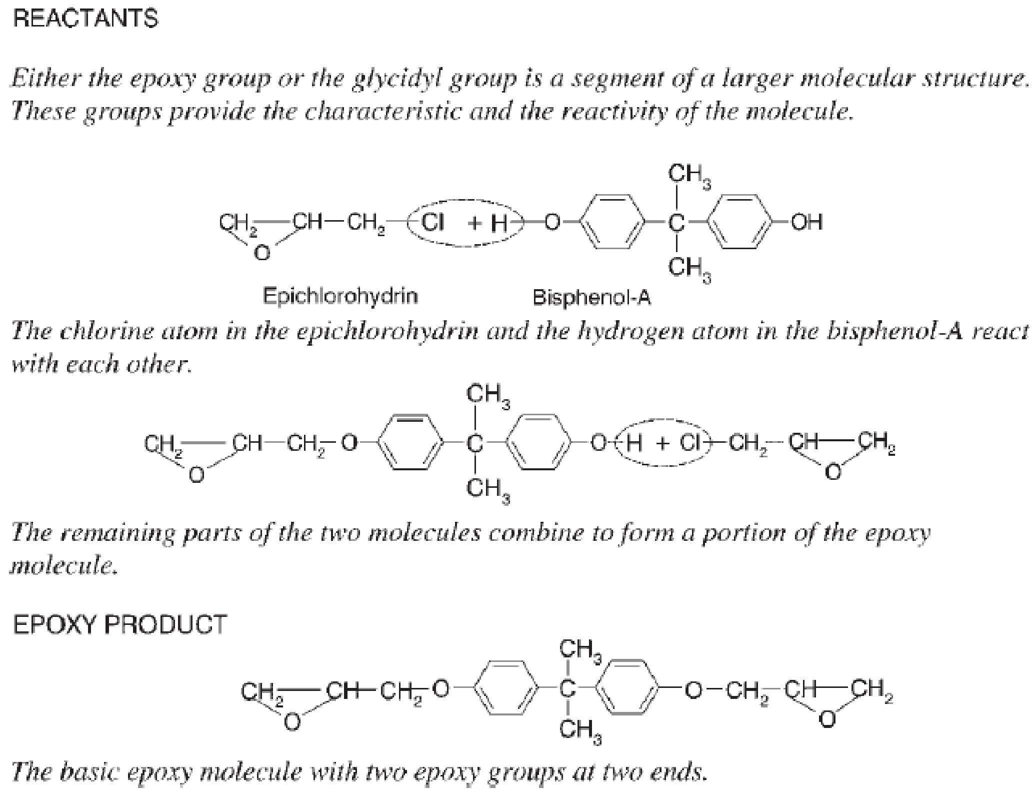


Figure 1.8:Reactants group and reaction to form epoxy [9].

The properties of the cross-linked polymers are dependent on the choice of curing systems in epoxies than in polyester. In addition to being the site that is used for cross-linking, the epoxy group is the reactive site and provides for good adhesion with the reinforcement or with the surface of another material.

CHAPTER 3

METHODOLOGY

In order to complete this whole project, there are several stages involve starting from fundamental study up until the testing. The first stage will be involving the fundamental studies in reading article, journal, researchers and also books. Next stage will be the method or procedure in fabricating the specimen using various methods to get the intended volume fiber fraction. After the fabrication has been done, the finalize method will be testing of the specimen to know the mechanical properties of the specimen. The overall chart of the process are as stated below:

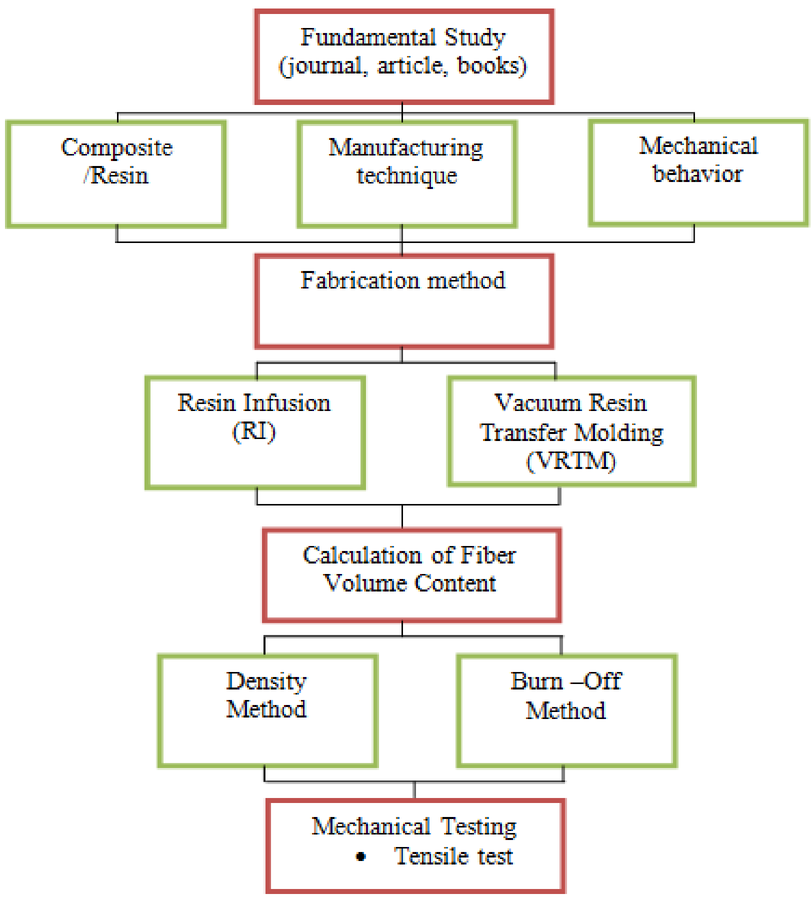


Table 3. 1:Flow chart of overall process

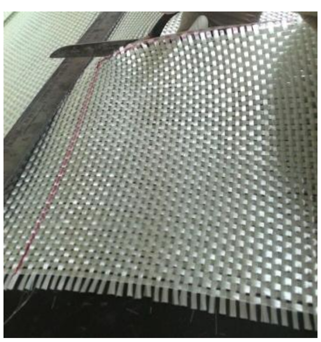
3.1 Specimen Preparation

The specimen will be fabricate in a laminate form that consist of E-glass plain woven roving fabric (800/m^2) and both polyester and epoxy resin. This e-glass fiber has been used as it is the most suitable and common material that is being used especially in aerospace industry as long in maritime application due to its mechanical properties.

Fabrication of the composite laminate

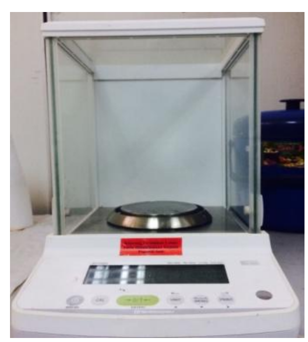
In this thesis, there will be two methods in producing the laminate that composed of E-glass fiber which are the resin infusion (RI) method and also the vacuum resin transfer molding (VRTM) or vacuum assisted resin transfer molding. Both methods are being conducted and the volume of fiber fraction is calculated. The calculation of volume of fiber fraction is necessary to know the percentage of fiber in the composite as it will give effect to the amount of moisture absorption as well as the mechanical properties.

The apparatus and material that have been used in this project are (a) E-glass woven roving fabric (800g/m^2), (b) Mash and spiral tube, (c), Weighing balance, (d) Polyester resin, (e) Hardener, (f) Epoxy resin, (g) Kerosene, (h) Biodiesel, (i) Distilled water,



(a)

(b)



(c)

(d) (e)

(g) (h)

(i)

Resin Infusion Method

The resin infusion method is a technique that uses vacuum pressure to drive the resin into a laminate. Compared to the traditional hand layup, the RI method that use vacuum bag provides a better improvement in term of the better fiber-to-resin ration, less wasted resin and more cleaner. A typical hand layup usually will derive an excess of weight of resin which eventually will weaken the part as the resin is brittle. By using RI, the resin usage will be lowered which increase the properties of the laminate itself.

RI Technique and Procedure

In RI method, the resin used is polyester resin. In this project, this is the typical RI method is being conducted to see the significant change of the volume fiber fraction of the laminate to be compared to the VRTM method as well as to understand about the general concept of how materials are used and arranged. The first step is by preparing the plate for the RI process. The plate is cleared from any dust . The plate is used so that the technique in transferring the resin into the laminate is easier and to move the laminate into the oven for the curing process. Then, the fiber is cut according to the measurement showed below:

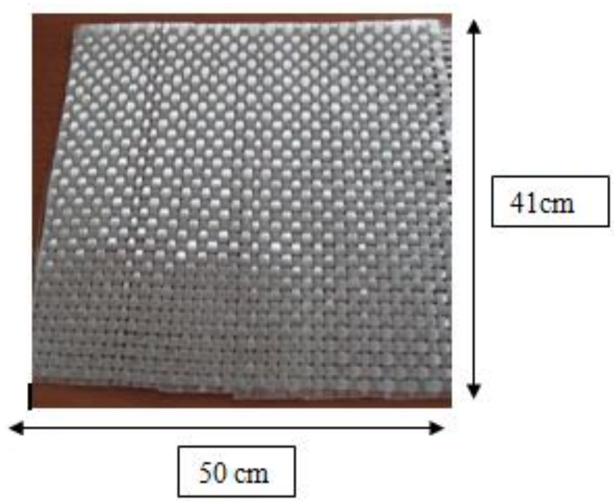


Figure 3. 1: : E-glass woven roving fabric