Manufacturing of Composite External Body for Hybrid Electric Vehicle

By

Mohd Izham Johar

Dissertation submitted in partial fulfillment
of the requirement
for the Bachelor of Engineering (Hons)
(Mechanical Engineering)

JUNE 2004

Universiti Teknologi PETRONAS
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
In partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by

____
(Dr. Abdul Rashid Abdul Aziz)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JUNE 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD IZHAM BIN JOHAR

ABSTRACT

Basically, the main objective of this project is to design and construct an aerodynamic hybrid electric vehicle and also minimizing the overall vehicle weight and body part by using other alternatives sources instead of steel.

The reason of concentrating on aerodynamic is due to the Coefficient of Drag (C_D) that exerts on the vehicle body and hence by reducing the force will increase the car performance. Moreover, the conventional car body is not practical to be used for hybrid electric vehicle. Thus, lightweight material has to replace the conventional usage of steel as car external body in order to maintain and increase the performance while reducing the fuel consumption.

The study involves on the existing car as the point of references by upgrading or changing the body part, which is not applicable for hybrid electric vehicle. In fact, feasibility study has to be done to understand the concept. The process flows start from the design, testing and until the construction of the prototype car as the practical solution.

ACKNOWLEDGEMENTS

The Final Year Project will not be a great successful to the author without the Linear Generator (LG) Lab staff commitment and undivided supports.

First and foremost, the author would like to express his special gratitude to the project supervisor and co-supervisor, namely Dr. Abdul Rashid Abdul Aziz and Mr. Mohd Saifuddin Mohamad, for their precious guidance and consultation at all times throughout the course of this study. The continuous and stimulus discussions were very much appreciated.

Apart from that, the author would also like to record his utmost appreciation to Associate Professor, Dr. Fakhruldin Mohd. Hashim, the Head of Mechanical Engineering Department, Mr. Saravanan Karuppanan and Mrs. Azuraien Jaafar, the Mechanical Engineering Programme Final Year Project Coordinator, for their patience, understanding and encouragement during the duration of this study.

Special thanks to Dr. Faiz Ahmad and Ir. Masri Baharom from the Mechanical Engineering Department for their consultation and assistance in the planning and strategizing of this study. A word of sincere gratitude to Mr. Anuar and Mr. Imtiyas, the technicians at the Material Lab of Mechanical Engineering Department, for their priceless cooperation and advices in the completion of this study.

Last but not least, the author is enormously indebted to all individual who has contributed to the completion of this project in one way or another but has been inadvertently not mentioned.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The final year project is primarily focused on the development and construction of Hybrid Electric Vehicle (HEV) which was initiated by Dr. Abd. Rashid Abd. Aziz with the co-supervision from Mr. Mohd Saifuddin Mohammad whom both are in the Mechanical Engineering Department. Apart from that, the project has undergone several stages with the involvement from Mechanical Engineering's Fifth Year students, in-house engineers and other external parties. It is due to completion on May 2004 in conjunction with the grand opening ceremony of UTP New Academy Complex.

Generally, Hybrid Electric Vehicles (HEVs) combine the internal combustion engine of a conventional vehicle with the battery and electric motor of an electric vehicle, resulting in twice the fuel economy of conventional vehicles. The combination offers extended range and rapid refueling that consumers expect from a conventional vehicle, with a significant portion of the energy and environmental benefits of an electric vehicle. The practical benefits of HEVs include improved fuel economy and lower emissions compared to conventional vehicles. The inherent flexibility of HEVs will allow them to be used in a wide range of applications, from personal transportation to commercial hauling.

Basically, the main aim of this project is to produce a HEV design that fulfills a certain set of requirements in the preliminary stage of the project which are aerodynamic interchangeable body and new architectural invention. Theoretically, the shape of a vehicle in motion causes the airflow to produce force acting on the surfaces of the vehicle which is known as drag force. Thus, through applying the concept of streamlining the vehicle body will reduce the effect of drag force acting on its surfaces such as frontal area and consequently increases its speed performance.

1.2 PROBLEM STATEMENT

1.2.1 Problem Identification

Normally, the obvious aerodynamics problem of conventional cars is caused by the Coefficient of Drag (C_D) which is normally ranged from 0.3 to 0.5. It is assumed to be high enough to cause extra fuel consumption to power the speed and affecting the car performance. Therefore, a vehicle possessing a Coefficient of Drag (C_D) ranging from 0.1 to 0.3 is capable to fulfill the criteria of being an aerodynamic.

The body shape is a major factor in overall vehicle efficiency. Aerodynamic drag rises exponentially with speed and the power requirements rise proportionally. The Coefficient of Drag (C_D) and the frontal area together are the variables that influence overall aerodynamic drag. These are both of major concern in the design of the boy shape. As to achieve a low Coefficient of Drag (C_D), the vehicle must separate the air with minimum disturbance.

1.2.2 Significant of the Project

Apart from focusing on the aerodynamic, the selection material of the car's body also has to be considered as a smooth surface and light material will help to reduce the drag coefficient and maintain the car performance such as using carbon fiber or fiberglass instead of steel which is totally have the different in weight. Thus by having lightweight material will reduced the overall vehicle weight.

Technically, through decreasing Coefficient of Drag (C_D) exerted onto the surfaces of the vehicle body less power will be needed to overcome the drag force acting on its body. Thus, the car will have higher energy efficiency with low fuel consumption.

However, in engineering, theoretical is one thing, while practicality is the most important ones. The theory might be right or wrong, based on the calculations done. Nevertheless, if this project works out as been suggested, it will be a major step towards the construction or fabrication of composite external body for the Hybrid Electric Vehicle.

1.3 OBJECTIVES AND SCOPE OF STUDY

The project has several vehicle restrictions and performance requirements. The car must accommodate a driver and passenger while employing current automotive standards (four wheels, conventional occupant seating positions, headlights, etc). An EV range of 40 – 60 km and capable of achieving highway speed ranging from 110 – 120 kph are among the performance requirements.

The main objective of this project is to demonstrate a series Hybrid Electric Vehicle platform for linear generator with the basic requirements and additional performance goals. Apart from that, the project requires the Body and Aerodynamics team to design and build a Hybrid Electric Vehicle with an aerodynamic shape. Thus, as to comply with aerodynamics requirement, the major concern of the project is to decrease the Coefficient of Drag (C_D) which should be in between 0.1 to 0.3 in order to increase the car performance while minimizing the fuel consumption.

In addition to that, the objective of the project is to design the vehicle with a minimum number of body parts in order to reduce the overall car weight. In order to reach the target, a strong, inexpensive and lightweight (locally available) material is the major concern which needs to be taken into account for material selection criteria. As far as the Body and Aerodynamics team is concerned, fiberglass has been chosen for the vehicle body to reduce weight and to allow ready fabrication of the unique shape of the prototype vehicle. At the same time, it is required to maintain the practical automobile geometry.

In general, the scope of this project is to design and build a Hybrid Electric Vehicle based on the existing car dimensions reference, which is Proton Wira, and try to come out with an idea as a solution prior to the body of the car such as the windshield or the trunk. Apart from that, researches are more on the literature review through browsing of reference books and info-searching on the websites. As a result, a design has to be produced as a solution based on the findings throughout the required time frame allocated. Development work on the constructing the prototype as the practical solution is the last part for this project scope. There will be an opportunity to use the tools and rare software in producing either the design or the real prototype. Furthermore, time management has to be emphasized as it is going to be a guide for everybody involved to the time frame of this project.

Specifically, each member of the project team has their own distributed task that needs to be completed. Basically, the project team has been divided into three main divisions which are the structural design and styling of external body team, the aerodynamic analysis of external flow team and manufacturing of composite of external body team. The manufacturing of composite of external body team is mainly involved in the selection of compatible material to be used for the external body and the appropriate fabrication method of composite of external body. In the later chapter, there are mainly three possible composite materials discussed and compared namely S-glass fiber glass, Kevlar49 and carbon fiber. Apart from that, the hand lay process is discussed and selected as the most appropriate fabrication method for the manufacturing of the external body. In fact, the step by step description of the fabrication method in the laboratory is shown in the later chapter.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 LITERATURE REVIEW

2.1.1 Importance of Light weighting

Reducing mass is the highest leverage means of reducing peak power available to vehicle designers. During steady state driving which is most of the time vehicles required only a small fraction of their maximum power output to sustain their speed. Peak power is needed during hard acceleration and in other high load driving conditions. The power required to achieve a given level of acceleration is determined to the first order by the vehicle's rate of change of kinetic energy:

$$P_{acc} = m/2\ [(v^2{}_1 - v^2{}_0)/t]$$

Where m = mass of the vehicle and its occupant, v_1 is the final velocity, v_0 is the starting velocity, and t is the time elapsed to reach the final velocity. It is clear from this equation of the mass vehicle will also halve the peak power required. In climbing a grade, mass is also primary determinant of power because potential energy also scales with mass:

$$P_{hill} = m.g.v.\sin(\theta)$$

Where g is the acceleration of gravity and θ is the angle of the incline. Moreover rolling resistance is also proportional to mass.

Thus in HEVs where cost per peak kilowatt is significantly higher than for conventional vehicles reducing mass is among the highest leverage factors for improving affordability. Through mass efficient design and certain application of lightweight materials, vehicles of any size can be made more than 50% lighter, compensating in whole or in part for the higher cost of the HEV drive system.

2.1.2 Composites Materials

Composite is a synergistic combination of two or more physically distinct materials. The properties of the composite material are superior, and possibly unique in some respects, to those of the individual constituents. This provides the main motivation for research and development into composite materials. Reinforced polymeric composites consist of three main elements:

- the reinforcement
- the matrix resin
- the interface between them.

Composite materials consist of two or more materials combined in such a way that the individual materials are easily distinguishable. A common example of a composite is concrete. It consists of a binder (cement) and reinforcement (gravel). The individual materials that make up composites are call constituents. Most composites have two constituent materials: a binder or matrix, and reinforcement. The reinforcement is usually much stronger and stiffer than the matrix, and gives the composite its good properties.

Composite can also be referred to as the combination of individual materials that are more than one. In the past, the most common composite was the mud brick with straws as the reinforced material. The most useful composite material, which has been introduced and used in the past until recently, is the steel reinforced concrete. This famous composite material is being used extensively for building construction. The latest composite material being commercialized broadly in the current world market is the Fiber Reinforced Plastics (FRP). This part will focus in details about FRP's design, manufacture and use of fibers, especially glass type that has been impregnated in a plastic resin. FRPs are widely used in most applications due to its high strength, lightweight, corrosion resistance, dimensional stability, good electrical resistance, etc.

Currently, the usage of FRP has extended to the fabrication of cars, airplanes, boats, consumer items, sporting equipment, tanks and piping. Unlike mathematical rules, the properties and characteristics of composites cannot be predicted by summing up the properties of its components. The combination of strong glass fibers with versatile as well as tough plastics will result in a very useful material compared to each of the original material. The main components of composites consist of mainly fibers, resins and color pigment.

The fibrous material used as the reinforcement in this project is S-glass woven fabric (WF). The matrix has to transfer loads between the reinforcement fibers, protect fibers from aggressive environments, support the fibers in compression, and provide adequate toughness to minimize damage initiation and growth.

Overall, the properties of the composite are determined by:

1. The properties of the fiber
2. The properties of the resin
3. The ratio of fiber to resin in the composite (Fiber Volume Fraction)
4. The geometry and orientation of the fibers in the composite

2.1.3 Fibers

Fibers, embedded within the resin matrix, contribute to the strength of the composites. The strong and stiff fibers will carry all the loads imposed on the matrix while the resin itself spreads the loads across the fibers. The most common types of fibers can be classified into two:

a) High tensile and stiffness fibers (non-glass)

The high tensile and stiffness fibers are produced from carbon, boron and aramid materials. They possess higher tensile strength and stiffness compared to the glass type and also cost more. Since the price is very expensive, this type of material normally serves special purposes such as bullet proof, collision region and better performance.

b) Glass fibers

Glass fibers exhibit good thermal and impact resistance, high tensile strength, good chemical resistance and good insulating properties. The glass fiber can be tailored to create several types of them which provide different types of strength. By combining the high tensile and stiffness fibers (non-glass) with common glass fibers, a new type of composite namely 'Hybrid composite' can be produced. This resulting composite has improved-overall-performance and also costs less.

High strength glass possesses greater strength and lower weight compared to the common one. These types are normally known as S-type glass in the United States, R-glass in Europe and T-glass in Japan. These glass fibers contain higher silica oxide, aluminum oxide and magnesium oxide than E-glass. S-glass is a lower cost glass fiber but it exhibits about similar performance.

Although glass fibers have very high chemical resistance, they can be easily eroded by leaching action when exposed to water. For example, an E-glass filament with a diameter of about 10-micrometer will be eroded by about 0.07%of its own weight when exposed to hot water for about 24 hours. The erosion rate will become slower with only 0.9% weight loss for 7 days of exposure when leached glass itself forms a protective barrier. Due to the reasons previously discussed, glass fibers should never be allowed to stand alone when exposing to water. In order to avoid the erosion problem, silane compound is coated to the glass fibers during manufacturing.

The diameter of the individual glass fibers is 10 μm. for the reinforcement of the thermoplastics, glass fibers are used in the form of short fibers 0.1 to 0.5 mm in length or as long fibers of 5 mm length. For reinforcement of sheet molding compound (SMC) the fibers used are approximately 50 mm long. Continuous fibers (strands) are used with thermoset casting resin and for glass mat reinforced thermoplastics (GMT).

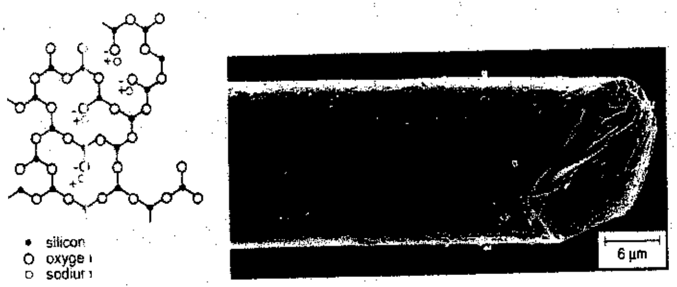


Fig. 4.62: Glass fiber
left: molecular model
right: SEM photograph

Figure 2.1: Glass fiber

	PA 6 (dry)	UP-resin	Glass fiber
Tensile strength [MPa]	80	50	1,200 - 1,500
Elastic modulus [MPa]	3,000	4,000	75,000
Poisson's ratio	0.4	0.35	0.18
Strain at failure [%]	5	2 - 8	2
Thermal expansion coefficient [1/°C]	$100 \cdot 10^{-6}$	$100 \cdot 10^{-6}$	$4.5 \cdot 10^{-6}$
Glass transition or melting temperature [°C]	75/220	40 - 140	600
Density [g/cm³]	1.14	1.25	2.52

Table 2.1: Properties of PA 6 (dry), UP resin and glass fiber

The starting material for the three most important glass fiber reinforcement is a strand consisting of at least 200 individual fibers. These strands are converted into fabrics, roving (30-60 strands) or mats as shown in the figure below. Mat consists of 50 mm long, randomly arranged fibers or of continuous fibers arranged in loops. The most important properties of reinforcing fibers are listed in Table 2.2.

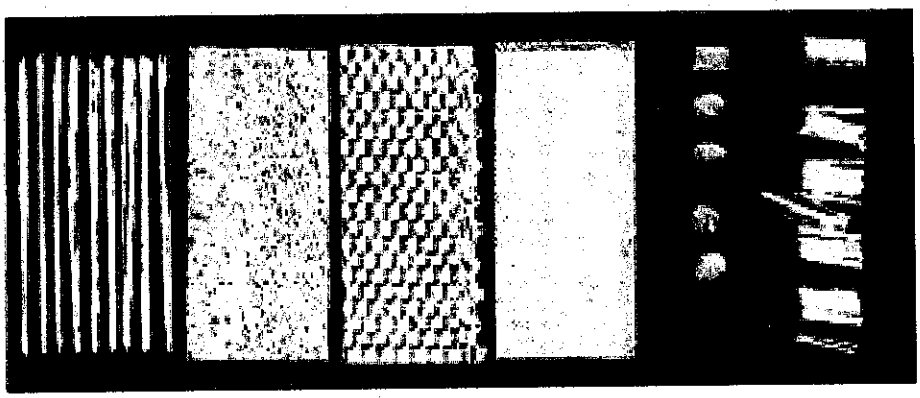


Figure 2.2: The most important glass fiber reinforcement

Fiber	Density	Tensile Strength	Elastic Modulus		Strain at Failure	Thermal Expansion Coefficient		Thermal Conductivity	Electric Resistance	Moisture Absorption
	ρ	σ_{II}	E_{II}	$E_{\perp}$	ε_B	α_{II}	$\alpha_{\perp}$	k	ρ_e	20°C 65% rel. hum.
	[g/cm³]	[MPa]	[GPa]		[%]	[10^{-6} °C^{-1}]		[W/mK]	[Ω cm]	[%]
E-Glass	2.5	2,400	73	73	3.0	5	5	1	10^{14} - 10^{15}	≤ 0.1
C-Fiber HM	1.96	1,750	500	5.7	0.35	-1.5	15		10^{-3} - 10^{-4}	≤ 0.1
HT	1.78	3,600	240	15	1.5	-1	10	17		
HTS	1.75	5,000	240	-	2.5	-1	10	17		
Aramid HM	1.45	3,000	130	5.4	2.1	-4	52	0.04 - 0.06	10^{15}	3.5

Table 2.2: Comparison of properties of glass, carbon and aramid fibers.

The diameter of glass fibers in the form of yarn for reinforcing fabrics is usually 9, 11 or 13 µm. Glass fibers themselves are isotropic for example their properties in the fiber direction are the same as those perpendiculars to the fiber direction:

Strength	newly drawn	3500	MPa
	Real	1500	MPa
Stiffness (elastic modulus)		75000	MPa
Thermal Expansion Coefficient		5×10^{-6}	C^{-1}
	For Comparison:		
	Steel	12×10^{-6}	C^{-1}
	Copper	17×10^{-6}	C^{-1}
	Aluminum	21×10^{-6}	C^{-1}
	Plastic	$80\text{-}200 \times 10^{-6}$	C^{-1}

The elastic modulus of glass fibers is about the same as that of aluminum and a third of that of steel; their tensile strength is higher than of most organic and inorganic fibers and in some cases is considerably higher than that of steel. Because of their relatively low density which is 2.5 g/cm3, glass fibers have very high weight based tensile strength. Textile glass fibers have a strain at failure of about 3%. Their thermal properties surpass those of other textile fibers. Even under constant load at 250 degree Celsius the mechanical properties remain unaffected. Textile glass fibers do not burn and are, therefore fire resistant.

2.1.4 Resin System

Composite with glass fibers and resin being mixed together is called the matrix resin. The matrix resin therefore protects the fibers from impact and environmental assault. In continuously reinforced composites, fiber properties will dominate the strength. While discontinuous reinforcement, the resin properties will dominate the strength.

Resin systems such as epoxies and polyesters have limited use for the manufacture of structures on their own, since their mechanical properties are not very high when compared to, for example, most metals. However, they have desirable properties, most notably their ability to be easily formed into complex shapes.

It is when the resin systems are combined with reinforcing fibers such as glass, carbon and aramid, those exceptional properties can be obtained. The resin matrix spreads the load applied to the composite between each of the individual fibers and also protects the fibers from damage caused by abrasion and impact. High strengths and stiffness, ease of molding complex shapes, high environmental resistance all coupled with low densities, make the resultant composite superior to metals for many applications.

Since Polymer Matrix Composites combine a resin system and reinforcing fibers, the properties of the resulting composite material will combine something of the properties of the resin on its own with that of the fibers on their own.

Any resin system for use in a composite material will require the following properties:

1. Good mechanical properties

When a composite is loaded in tension, for the full mechanical properties of the fiber component to be achieving, the resin must be able to deform to at least the same extent as the fiber.

2. Good adhesive properties

High adhesion between resin and reinforcement fibers is necessary for any resin system. This will ensure that the load was transfer efficiently and will prevent cracking or fiber / resin debonding when stressed.

3. Good toughness properties

Toughness is a measure of a material's resistance to crack propagation, but in a composite, this can be hard to measure accurately. However, the stress / strain curve of the resin system on its own provides some indication of the material's toughness.

4. Good resistance to environmental degradation

Good resistance to the environment, water and other aggressive substances, together with an ability to withstand constant stress cycling, are properties essential to any resin system.

2.1.5 Reinforcement

Reinforcement of plastic by fibers has been employed successfully as means of improving the mechanical properties of manufactured products. The reinforcing fibers can be introduced either in a continuous (long) or discontinuous (short) form.

The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the neat resin system. All of the different fibers used in composites have different properties and so affect the properties of the composite in different ways.

The mechanical properties of most reinforcing fibers are considerably higher than those that un-reinforced resin systems. The four main factors that govern the fiber's contribution are:

1. The basic mechanical properties of the fiber itself
2. The surface interaction of fiber and resin (the 'interface')
3. The amount of fiber in the composite ('Fiber Volume Fraction')
4. The orientation of the fibers in the composite

The ratio of the fiber to resin derives largely from the manufacturing process used to combine resin with fiber. This is called the fiber volume fraction. In general, since the mechanical properties of fibers are much higher than those of resins, the higher the fiber volume fraction the higher will be the mechanical properties of the resultant composite. In practice there are limits to this, since the fibers need to be fully coated in resin to be effective, and there will be optimum packing of the generally circular cross-section fibers.

Typically, with a common hand lay-up process as widely used in the boat-building industry, a limit for Fiber Volume Fraction is approximately 30-40%. With the higher quality, more sophisticated and precise processes used in the aerospace industry, Fiber Volume Fractions approaching 70% can be successfully obtained.

Fabric types are categorized by the orientation of the fibers used, and by the various construction methods used to hold the fibers together. The four main fiber orientation categories are unidirectional, Woven, Multiracial, and Other/random. The geometry of the fibers in a composite is also important since fibers have their highest mechanical properties along their lengths, rather than across their widths. This leads to the highly anisotropic properties of composites, where, unlike metals, the mechanical properties of the composite are likely to be very different when tested in different directions. This means that it is very important when considering the use of composites to understand at the design stage, both the magnitude and the direction of the applied loads. When correctly accounted for, these anisotropic properties can be very advantageous since it is only necessary to put material where loads will be applied, and thus redundant material is avoided.

2.1.6 Manufacturing Process

Every material possesses unique physical, mechanical and processing characteristic and therefore a suitable manufacturing techniques must be utilized to transform the material to the final shape. There are four basic steps involved in composite part fabrication. All composite manufacturing process involves the same four steps, although they are accomplish in a different ways.

1. Impregnation/wetting

   In this steps, fibers and resin are mixed together to form a lamina

2. Lay-up

   In this step, composite laminates are formed by placing fiber resin mixtures or prepress at desired angles and at places where they are needed.

3. Consolidation

   This step involves creating intimate contact between each layer of prepregs or lamina.

4. Solidification

In thermoset composite (polyester or epoxy based), the rate of solidification is depend on the resin formulation and cure kinetics. Heat is supplied during processing to expedite the cure rate of resin. Faster cross-linking process is obtained when the temperature is high.

Hand lay-up process

This process involves the manual placement of fiberglass reinforcement, and the saturation of the glass is done either by the bucket and brush method or a mechanical dispensing method. In other words, reinforcement is placed by hand while the resin may be applied using several methods.

When laminating light reinforcement, the glass fiber can be laminated with resin from the top. When the reinforcement is heavier, the fiber glass should be 'back wet' for efficient saturation. In principle, the glass should be pushed down into the resin while the resin should be pushed down into the glass.

Back wetting can be accomplished in two ways such as wet the mould surface then place and position the reinforcement; or place the reinforcement then fold back one half, back wet and fold back, then repeat the process on the other half.

The resin should not be over applied because when it is on the glass, it takes time to remove it or the end product will result in resin rich.

In this process, liquid resin is applied to the mold and reinforcement is placed on top. A roller is used to impregnate the fiber with the resin. Another resin and reinforcement layer is applied until a suitable thickness builds up.

- Basic Raw Material

Woven fabrics of glass, Kevlar and carbon fibers are used as reinforcing material. Epoxy and polyester are used during the hand lay-up process.

- Tooling Requirement

The mold design for hand lay-up process is very simple as compared to other manufacturing processes because the process required mostly a room temperature to cure environment with low pressure. Steel, wood or other materials are used as mold materials for prototyping purpose. A roller is also required in this process for the uniformly pressure distribution around the surface.

- Making Part

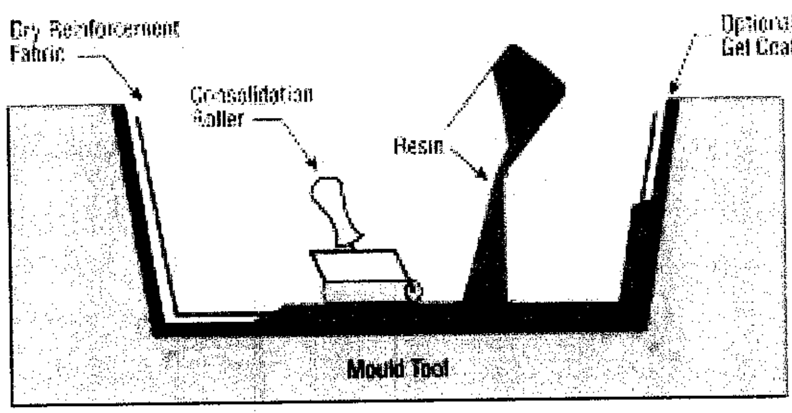


Fig 2.3: Schematic of the hand lay-up process

A schematic of the hand lay-up process is shown above, where the thickness of the composite part is built up by applying a series of reinforcing layer and liquid resin layers. A roller is used to squeeze out excess resin and create uniform distribution of the resin throughout the surface.

- Method of Applying Heat and Pressure

The hand lay-up process is normally done under room temperature conditions. Pressure is applied using rollers during lamination during the curing process, there is no pressure or sometimes-vacuum bagging is used to create good consolidation between the layers as well as to remove entrapped air.

2.2 THEORY

2.2.1 Rule of Mixture

Fiber volume fraction is defined as

$$V_f = \left(\frac{\text{Volume of fibre}}{\text{Total volume}}\right)$$

As a result, the volume of matrix is given as

$$V_m = \left(\frac{\text{Volume of matrix}}{\text{Total volume}}\right)$$

With

$$V_m = 1 - V_f$$

We can convert from mass fraction to volume fraction and vice versa. If ρ_f and ρ_m are the specific mass of the fiber and matrix, respectively, we have

$$V_f = (M_f/\rho_f) / [(M_f/\rho_f) + (M_m/\rho_m)]$$

$$M_f = (V_f\,\rho_f) / [(V_f\,\rho_f) + (V_m\,\rho_m)]$$

where M_f and M_m are the mass of fiber and mass of matrix respectively.

So the Rule of Mixture is **$X_c = X_f V_f \text{ x } X_m(1-V_f)$**

CHAPTER 3

METHODOLOGY

In order to proceed with the project, a clear and concise methodology is important to ensure that the flow of the project would be smooth and organized. There are few steps taken to ensure that the experiment will be handled successfully for the time period being. Below is the flow chart of the project methodology.

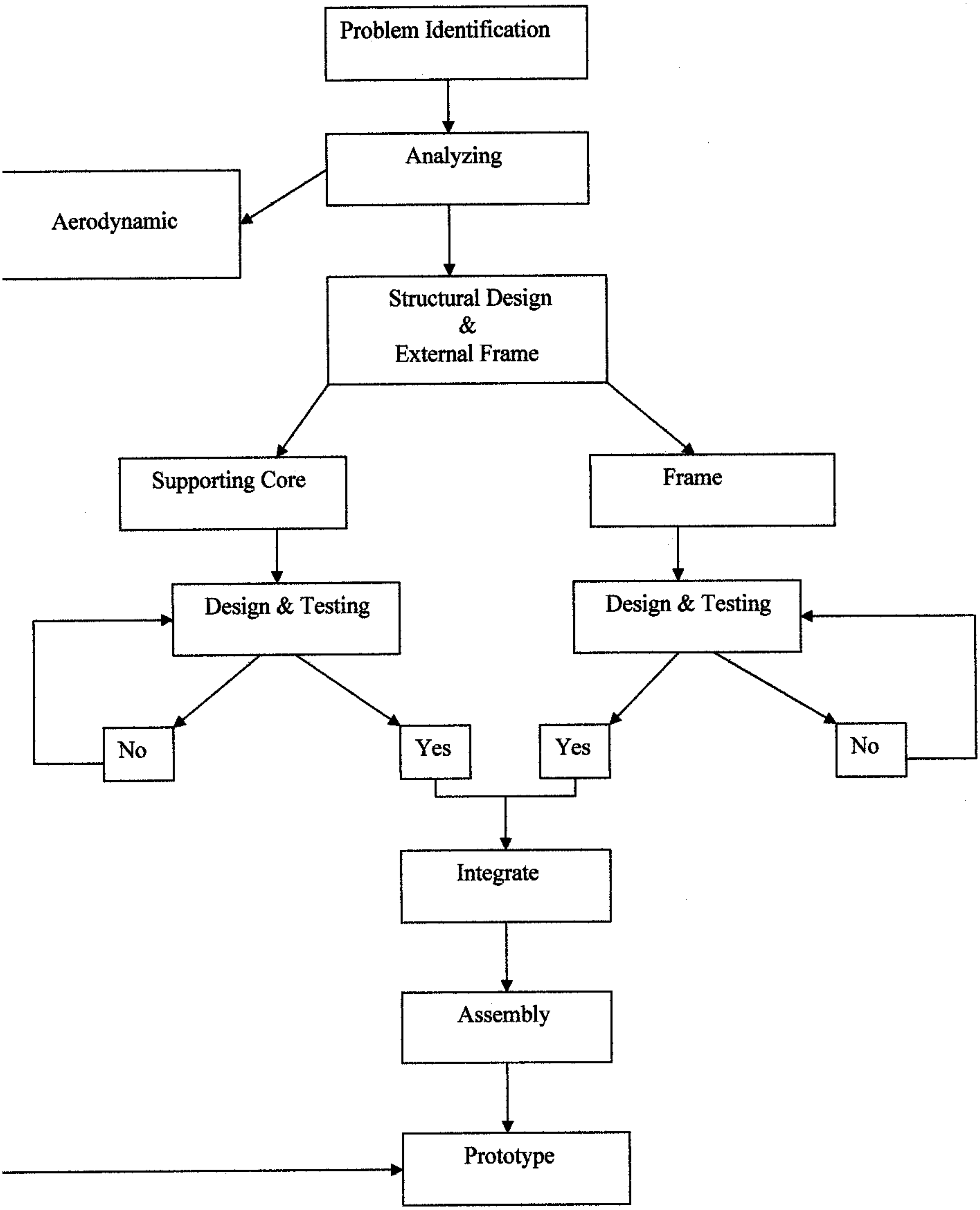


Figure 3.1: Flow chart of the project methodology

3.1 Procedure Identification

In performing this project, there are procedures that need to be followed in order to get this project runs smoothly and produce great results. The proper planning is essential in order to make sure the success of this project. This includes producing Gantt charts (refer Appendix A) which are used throughout the project duration as guidance in term of time management. Research plays an important tool that must be done by the author in order to gather the information about project. This steps lie under the literature analysis that must be done by the author. The author has read a few books related to the project and all-important data then recorded. The internet also contributes a lot in obtaining sources the author need. A few associated websites that discuss this matter also been visited. Besides that, thesis and reports about project that associates with mechanical properties of composite materials also been used as the reference.

In order to get things done properly, the author also needs to make weekly meeting with the supervisor. This meeting is essential for the author to present all findings throughout the week, and to report all progress on the project, by present it on the weekly report. During the meeting, the author also can confront any troubles and difficulties faced and seek for advice and guidance to solve these arising problems.

The procedure plan of this project is as follows:

- Methodology and project work

Based on the literature analysis and problem definition, the author will determine the appropriate method to approach the problem. The method is simplified in the figure below:

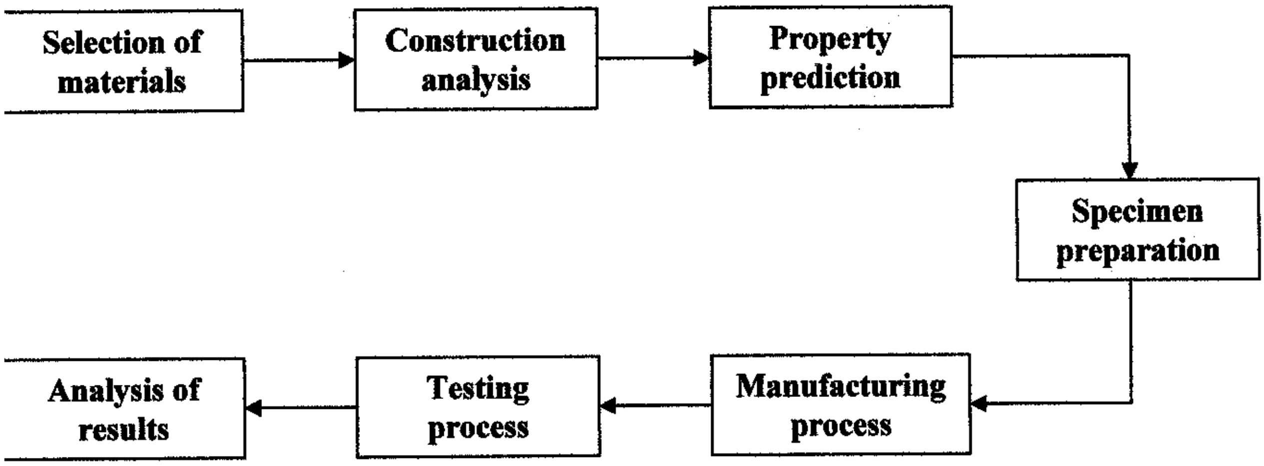


Figure 3.2: Flow chart of methodology for laboratory work

1. Selection of materials

   The behaviors and performance of a finished product depend on the types of materials used in making part. There are two major reasons why an engineer becomes involved in the materials selection process:

a) To redesign an existing product for better performance, lower cost, increased reliability, decreased weight, etc

b) To select material for a new product or application

   After done some research and discussion with the supervisor for the material selection, the author found that the polyester and epoxy resin is going to be choosing as the matrix materials. For the reinforcement fillers, the S-glass woven fabric (WF), Kevlar49 and Carbon fabrics have been chosen.

2. Construction analysis

   Unlike conventional materials, it is necessary with composite to determine the amount and type of fiber to be used. The author may want to know the thickness of laminate for given amount of fiber and resin and want to know how much materials must be used to achieve it. The quantity of reinforcement and resin in the mixture is required to achieve a particular thickness in the subject of the construction analysis.

3. Property prediction

   After have decided about the amount of volume fraction of fiber that going to be used which are (15%, 30%, 45% and 60%), their properties can be determined by using the Rule of Mixture. The calculation of these predetermined properties is shown in Chapter 4.

4. Specimen preparation

   Before the manufacturing process, the amount of resin and reinforcement that going to be used must be prepared first. The amount of it depends on the how much weight fraction or volume fraction that the author has decided to manufacture the composite and hybrid composite.

5. Manufacturing process

   Composite materials are converted into components by a set of unique processes. In this project, as stated in Chapter 2, the techniques used for composite fabrication is the hand lay-up process. For this semester, the author has done the practice of this technique to manufacture a 20 cm x 20 cm plate of the epoxy/glass (WF) composite and a car part. The details of laboratory work are explained in later chapter.

6. Testing process

   Testing phase is important since the author wants to study the mechanical properties of fabricated composite and hybrid composite. The test for the composite and hybrid composite is done through the tensile test. It is done by using the Universal Testing Machine.

Composite and hybrid composite that are manufactured using the selected material is summarizing in the table below:

No	**P-type composite**	**E-type composite**
1	Polyester/Glass (WF)	Epoxy/Glass
2	Polyester/Carbon	Epoxy/Kevlar49
3	Polyester/Kevlar49	Epoxy/Carbon

Table 3.1: Composite and hybrid that going to be manufactured

The entire plate (20 cm x 20 cm) of composite and hybrid composite was manufactured with different fiber volume fraction which are 15%, 30%, 45% and 60% Volume Fraction.

3.2 Tools/Equipment Required

3.2.1 Material Used

- Polyester resin

  Unsaturated polyester resins become one of the most demandable items due to its low cost, ease of handling and good chemical resistant properties. One of the main ingredients that determine the quality of polyester is orthopolyesters which uses orthophthalic acid. Isopolyester contains isophthalic acid as an important ingredient and exhibit superior chemical and thermal resistance to orthoplyesters.

- Epoxy resin

Epoxy resins also belong to the thermoset group. Its main application is in the fabrication of structural aerospace. It costs more money than polyester's but it offers less shrinkage and higher strength properties at moderate temperatures. Other advantages include excellent corrosion resistance to solvents and alkalis, some acids. Similar to polyester, epoxy can be used in most composite manufacturing and can be formulated to provide various properties. Cross-linking is more dependent on the hardener systems in epoxy resins. Complete curing requires more time than polyesters and no by products are used during cure. Performance of properties such as toughness and shrinkage, improved chemical resistance and heat distortion temperature are very much affected by the cross linking density.

Figure 3.3: Epoxy and Polyester Resin

- Glass fabrics

The fibrous material used as the reinforcement in this project is S-glass woven fabric (WF). These fabrics are fabricated on looms in various weights, weaves and widths. Its advantage is that it allows faster composite fabrication. The disadvantage is that it has lower tensile strength compared to using two laminates. This is because under tensile loading, the straight fibers tend to straighten out; while the horizontal ones are crimped as they pass over under one another. This phenomenon causes stress in the resin matrix system.

Woven roving is a thick fabric used for heavy reinforcement especially in hand-layout activities. Since the weave is very course, it wets quickly and can speed up work. It also costs less.

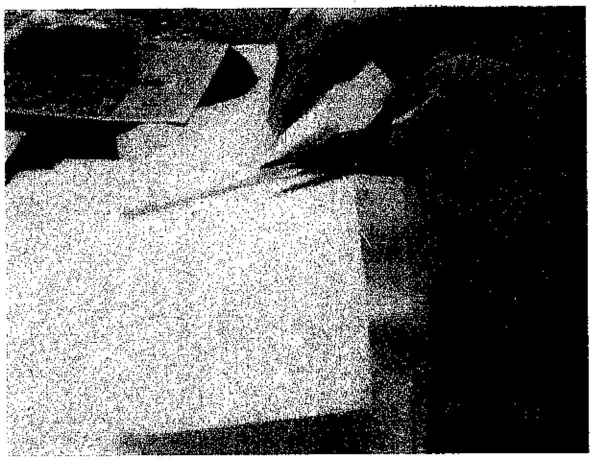


Figure 3.4: S-glass fabrics

- Carbon fabrics

Advanced composites such as carbon-reinforced polymers represent the most logical replacement for steel where significant weight reduction (grater 60% compared with steel) is desired. The two most widely cited obstacles to the use of carbon composite are the high cost of the raw materials.

- Kevlar49 fabrics

Kevlar 49 is a structural grade aramid fabric used for reinforcement when combined the appropriate epoxy, polyester or vinyl ester resins.

- Super white pigment

The super white pigment is used to give the white color appears on the fiber glass finished product. It is just meant for aesthetic purpose.

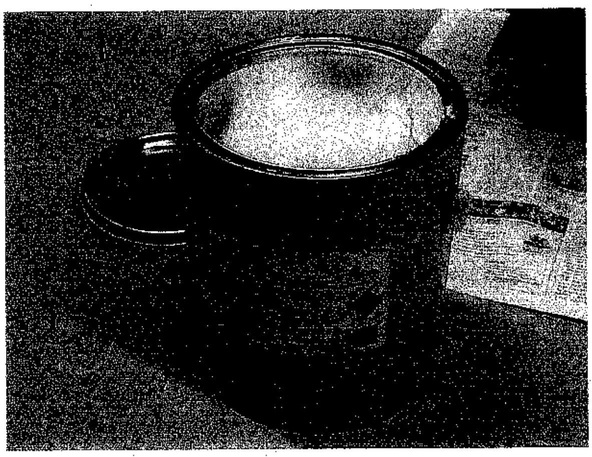


Figure 3.5: Super white pigment

- Hardener

In the fabrication work, the Methyl Ethyl Ketone Peroxide (MEKP) hardener has been used to mix with the resin system. The purpose of mixing the hardener in the resin system is to ensure the mixture can be cured more quickly.

Figure 3.6: MEKP hardener

3.3 Literature Review and Theory

In order to understand the project, literature review is vital in undermining the objectives of the project. This is because, from literature review, the whole concept of the project will be explained and thoroughly understood. Hence, from the reference guide such as books, journals and websites; lots of information can be gathered.

3.4 Equipment Identification

Before proceeding with the fabrication work, it is important to know the equipment or apparatus used in the laboratory for this project. There are:

3.4.1 Mold

A fiber mold is used to fabricate another finished product of fiber glass car part. For this mold, it is obtained from one of the car styling workshop in Kuala Lumpur. It has been brought back to the UTP Mechanical Engineering lab for further fabrication work.

Figure 3.7: Mold

3.4.2 FRP roller

FRP roller is used to promote the saturation of reinforced glass, to compact the laminate and to remove air voids. The size of the roller must match the work. Rolling on flat areas will require larger diameter and width of the rollers. When rolling along radii, the diameter of the rollers should match that of the radii to be rolled.

Figure 3.8: FRP roller

3.4.3 Mould release wax

Mould release wax has been used in the earlier stage of fabrication work. It is used before a mould is fabricated so that it is free of dirt and dust. Most importantly, the wax is applied so that the mould which needs to be fabricated would be easily released later on.

Figure 3.9: Mould release wax

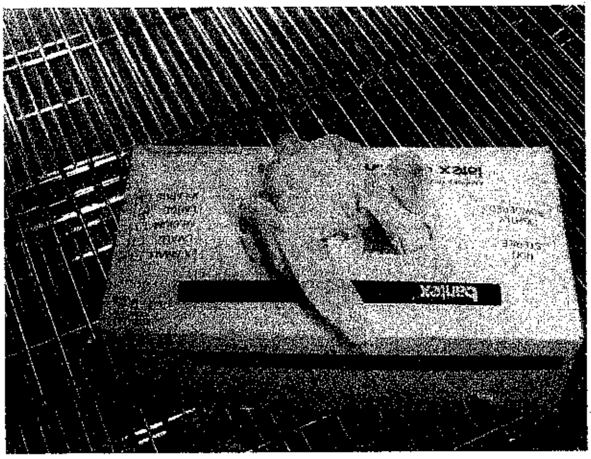


Figure 3.11: Latex glove

Figure 3.12: Plastic apron

3.4.6 Portable grinder machine

The portable grinder machine is used during the post laminating work. It is used after a mould has been fabricated. It is utilized as to grind the excessive part of the mould which can be considered as unnecessary. Since the mould or final fiber glass product is very hard to be cut by using a scissor, the portable grinder machine could be handy for that particular task.

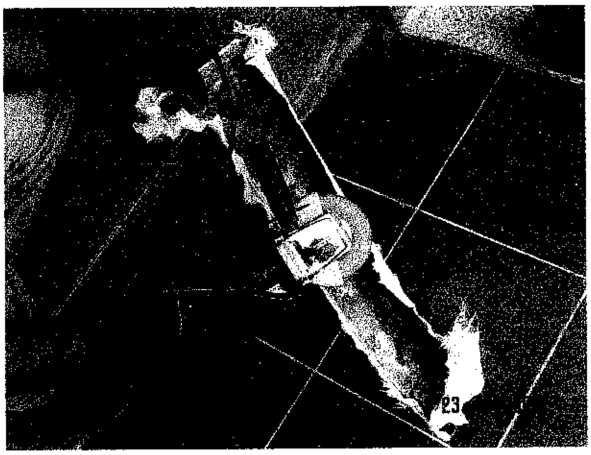


Figure 3.13: Portable grinder machine

3.4.7 Plastic bucket

Plastic buckets are used as containers to fill the mixture of resin and hardener system.

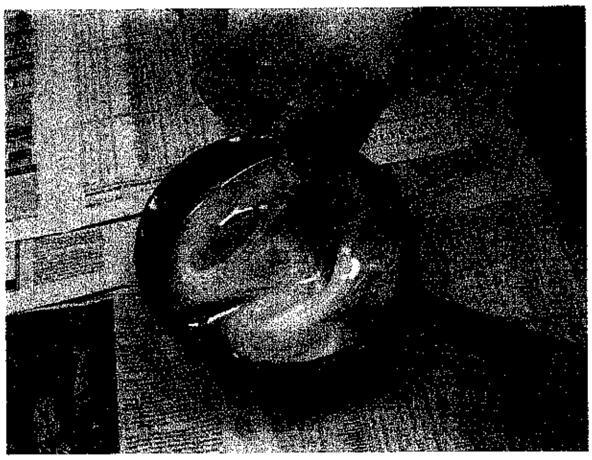


Figure 3.14: Plastic bucket

3.4.8 Scissor

Scissor is widely used during the laminating work. In fact, it also used before the laminating has taken place. Particularly, the scissor is used to cut the fiber material. During the laminating work, it is important to use scissor to cut the excessive fiber material on the mould before the fiber material cures or dries.

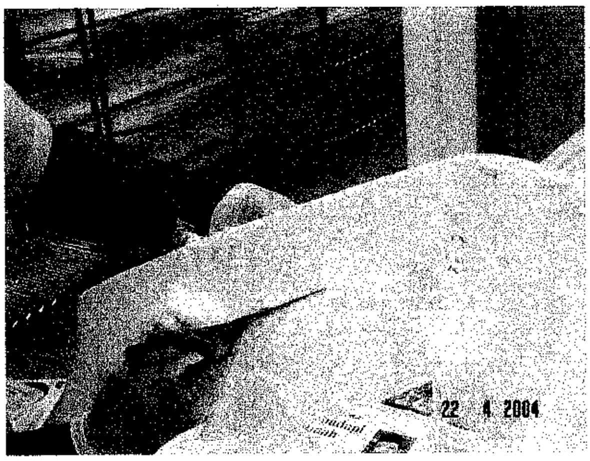


Figure 3.15: Scissor

3.4.9 Universal testing machine

This type of testing machine is a universal type testing machine designed for the tension, compression, transverse, and bending test on metallic materials and others. Together with a variety of optional testing attachments, the machine provides a number of tests on nonmetallic materials such as plastics, rubber, rubber moldings, wood, and ceramic products, etc, including composites used in this study.

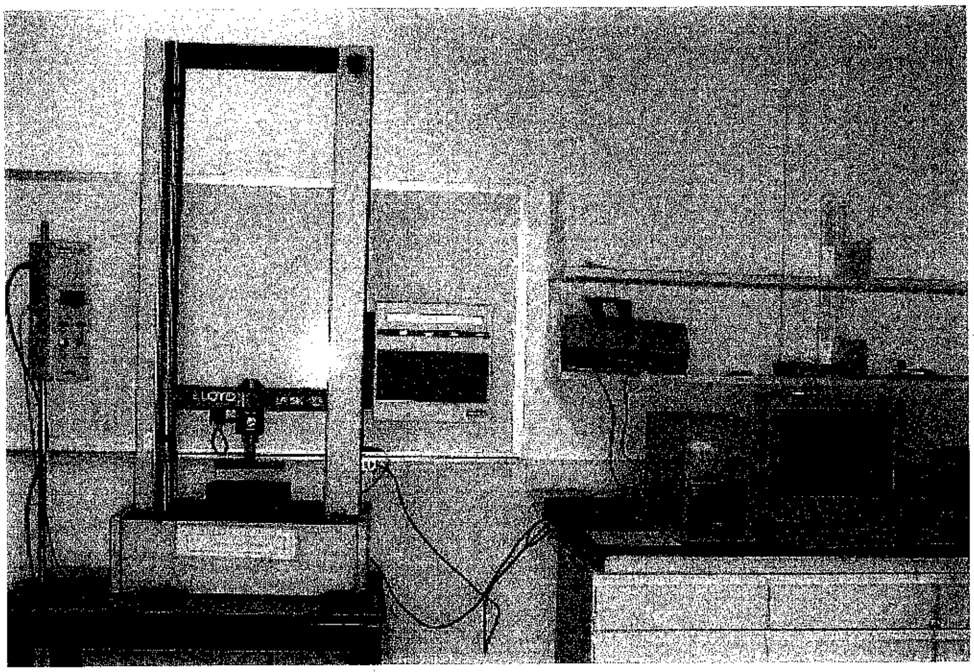


Figure 3.16: Universal Testing Machine manufactured by LLOYD Instruments, Germany

CHAPTER 4

RESULT AND DISCUSSION

4.1 Laboratory Work

4.1.1 Area Density Determination

The author has done the laboratory work for this semester in order to complete the construction analysis and specimen preparation. The S-glass fabric (WF) area density is going to be determined in this lab work.

The following procedure was adopted for construction analysis and specimen preparation. First, cut the 10 x 10 cm of glass fiber. This fabric is weighted using the weight machine. Then the weight of that glass fiber is recorded. From this experiment, the weight of 10 x 10 cm fabrics is equal to the 4.08 g.

$$0.1m * 0.1m = 4.08g$$

So the glass fiber (NWF) area density, $= \dfrac{4.08g}{0.1m * 0.1m}$

$$= 408\frac{g}{m^2}$$

Similar procedure was repeated to identify the fiber area density for carbon and Kevlar49 fabrics.

4.1.2 Specimen Preparation

After getting the area density of the related fiber, the specimen preparation calculation is done by the author. This is important since the author wants to know the amount of the fiber and resin must be used in order to come out with the composite product with the desired volume fraction.

For this lab work, the author wants to produce a 20 cm x 20 cm plate of epoxy/glass (WF) composite with the 15% volume fraction. Using the rule of mixture (ROM), 15% volume fraction is equal to 29% weight fraction.

Area density glass (NWF) $= 408 \frac{g}{m^2}$

Weight of 20 x 20 cm of glass fiber $= 0.2m * 0.2m * 408 \frac{g}{m^2}$

$= 16.32$ g

So if weight fraction of fiber 0.29 $= 16.32$ g

The weight of composite $= \frac{16.32g}{0.29}$

$= 56.28$ g

Hence the amount of resin used $= 56.28\text{ g} - 16.32\text{ g}$

$= 39.96$ g

So, the weight used in order to get 15% of volume fraction composite is:

Resin = 39.96 g

Fibre = 16.32 g

The similar procedure was repeated for the calculation of the specimen preparation for composite and hybrid composite with different volume fraction and different fiber.

4.1.3 Composite Manufacturing

Throughout the study, the author has the opportunity to manufacture a 20 cm x 20 cm plate of composite and fabricate a car part. The composite that has been manufactured is epoxy/glass (WF) composite with 15% volume fraction. It has been done using the hand lay-up methods.

All the above procedure (explained in Chapter 2 and Chapter 3) is followed including the specimen preparation before fabricating the composite. This is important since the author wants to produce the composite with exactly desired volume fraction.

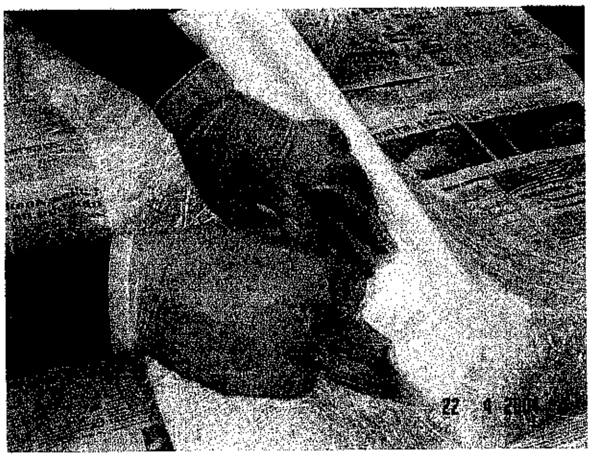
The procedure to produce a car part of polyester/glass composite is described below:

1) A release agent is applied to the mold surface to remove the impurities

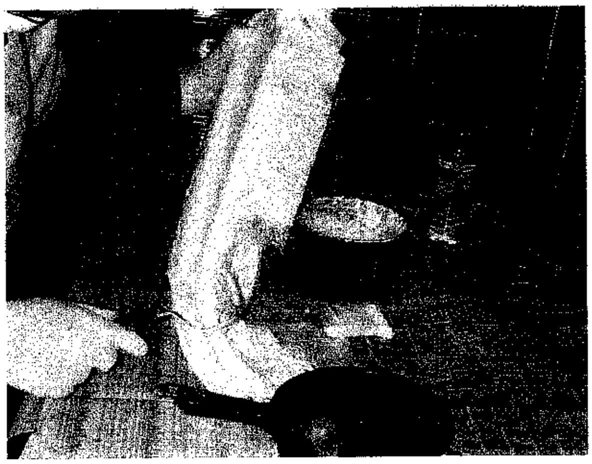
2) The gel coat is applied to create a clean and shiny surface finish on the outer surface

3) Polyester is weighted according to the desired weight and was homogenized with hardener in the ratio of 10:1.

4) Then the desired size of glass fabric reinforcing layer is placed on the mold surface and then it is impregnated with polyester resin



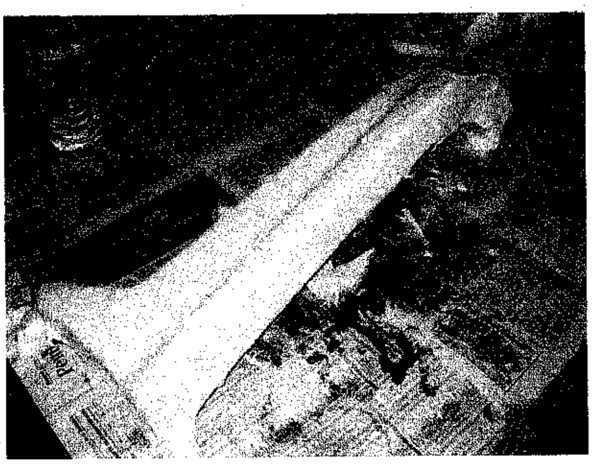
5) Using a roller, polyester is uniformly distributed around the surface



6) All the polyester resin that has been specifically prepared is placed into the mold.

7) The polyester is uniformly distributed around the surface

8) Finally the part is allowed to cure at room temperature, or at elevated temperature



4.1.4 Techniques of Laminating

The primary objectives of FRP laminating processes are:

- To properly place or distribute the glass reinforcement on the mould
- To saturate the reinforced glass with resin
- To remove entrapped air
- To use the proper resin to glass ratio

With regard to air trapped and removal concept, when glass reinforcement is saturated with resin, some air bubbles are trapped within the laminate. The trapped air will cause failure from cosmetic to structural problems due to the internal defects. The idea of removing air from the laminate is to consolidate the laminate so that there is no room for extraneous air bubbles. The goal is actually to push the saturated glass reinforcement uniformly down to the mould surface so that air void can be squeezed out from the laminate

4.1.5 Mechanical Testing of Injection Molding Thermoplastics Composite

<u>Test Specimen Preparation.</u>

A test specimen preparation for determination of mechanical properties of samples was prepared by an injection molding machine. Table 4.1 and Table 4.2 show the parameter used for reinforcing short fiber with polyethylene and volume fraction of specimens respectively.

Cycle time(s)	Mold Temperature (°C)	Shot size(g)	Injection pressure (kg/cm^2)
4 s	30	20	130

Table 4.1: Main parameter of injection molding

No.	Polypropylene volume of fraction (%)	Fiber glass volume of fraction (%)	Specimen testing
1	95	5	Tensile test
2	90	10	
3	85	15	
4	80	20	
5	85	25	

Table 4.2: Volume fraction of specimens

<u>Mechanical Testing</u>

Tensile Test

Tensile properties were determined according to ASTM D-638 using the dog bone-shaped injection molding specimen using Universal Testing Machine manufactured by LLOYD Instruments, Germany. Applied constant load is 5 kN. The specimen was 10mm in width and 4.3mm in thickness with gauge length 109.4mm. The cross speed was kept 10mm/min.

Sample no.	Volume fraction of fiber(%)	Elongation (mm)	Young's Modulus(MPa)	Tensile strength(MPa)
1	0	9.00	1182	30.15
2	5	7.03	1222	32.47
3	10	3.94	1262	45.74
4	15	3.51	1536	64.93
5	20	2.27	1822	70.13

Table 4.3: Result of tensile test

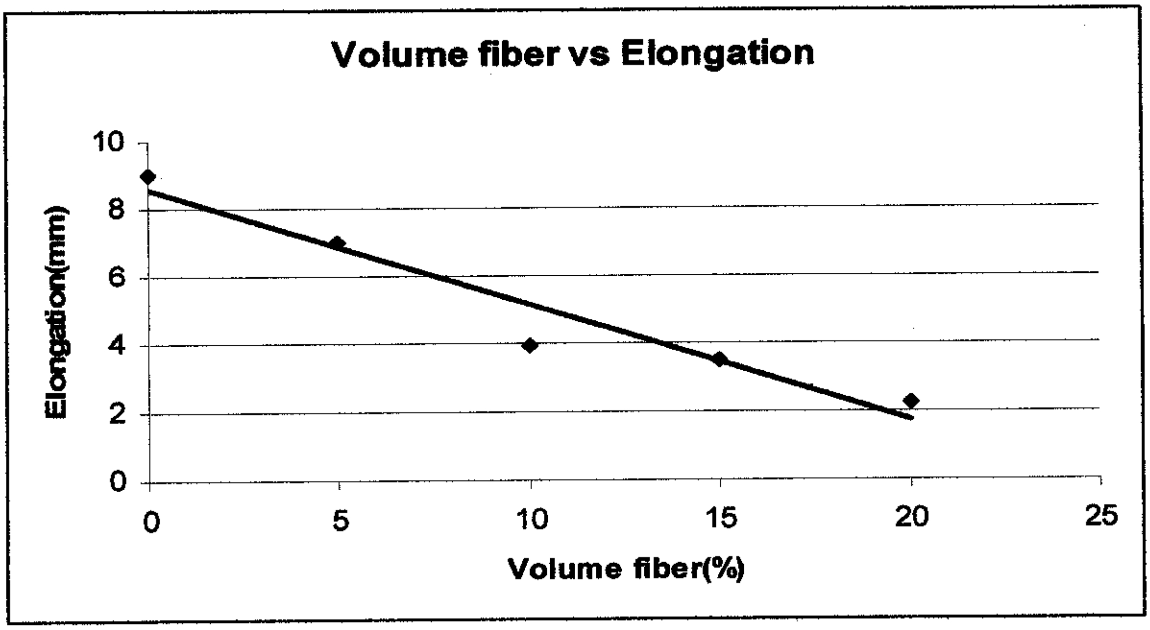


Figure 4.1: Graph of Volume fraction of fiber vs Elongation

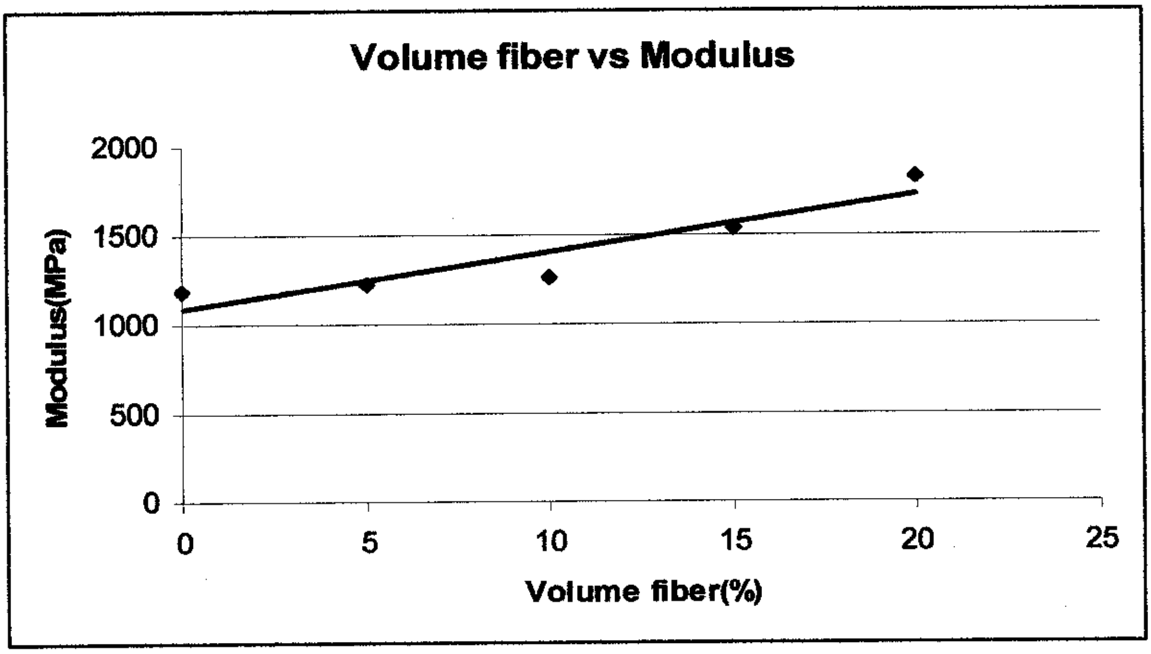


Figure 4.2: Graph of Volume fraction of fiber vs Young Modulus

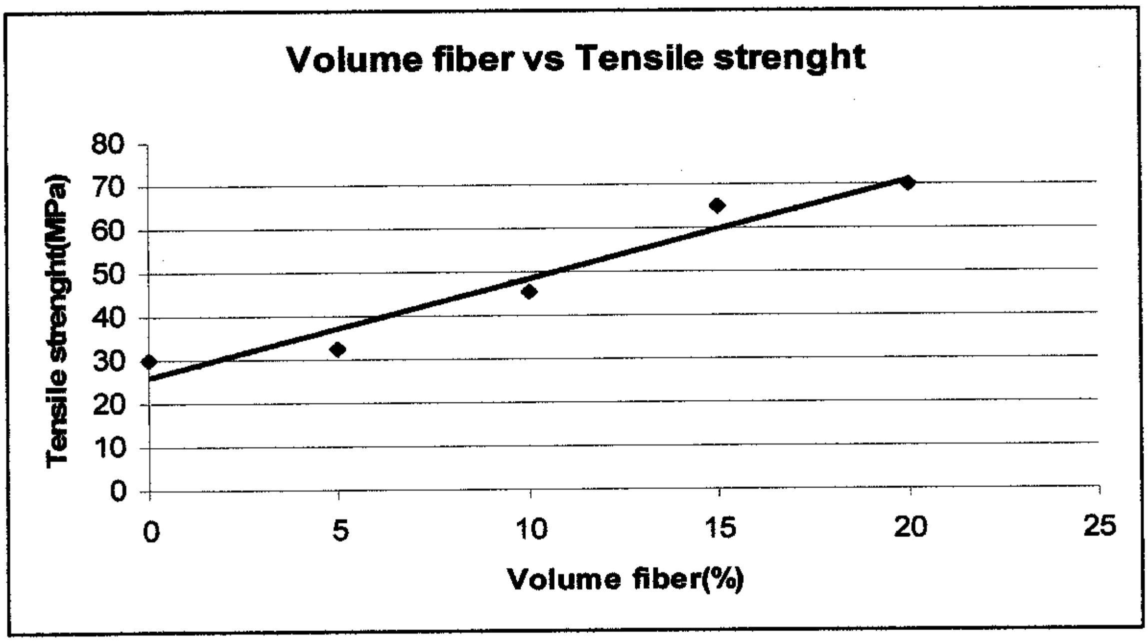


Figure 4.3: Graph of Volume fiber vs Tensile strength

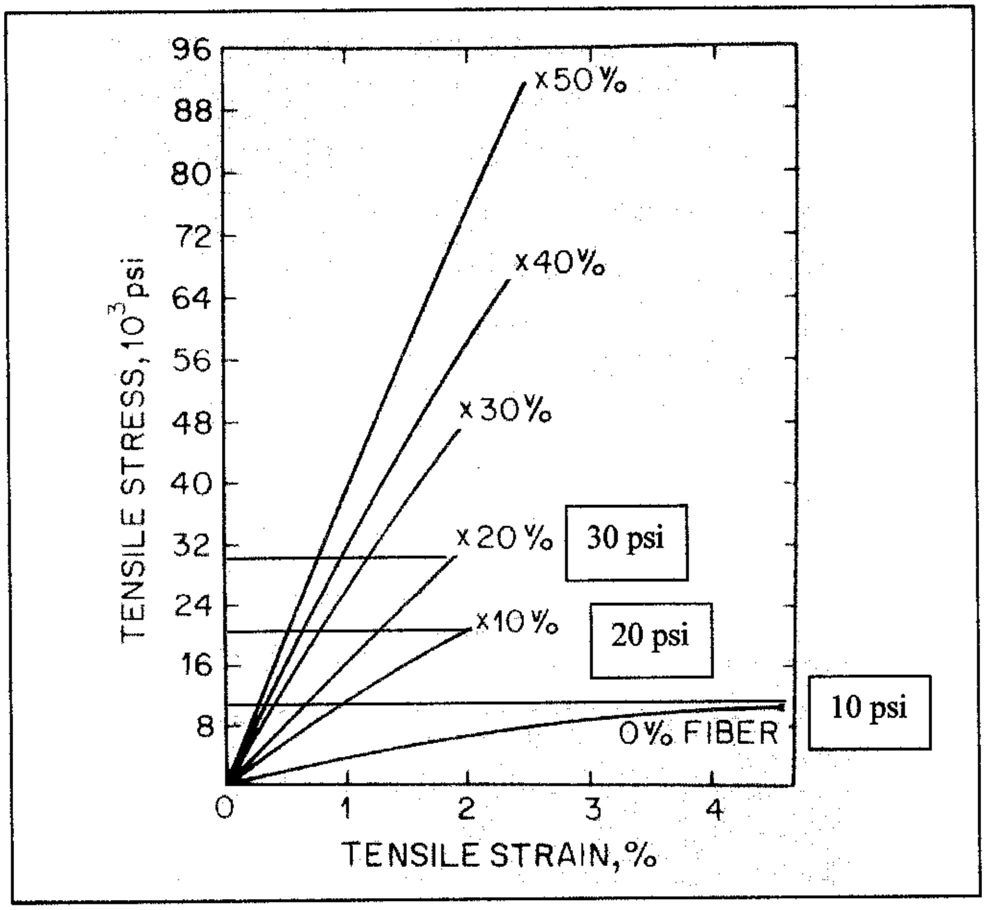


Figure 4.4: Theoretical value of tensile strength of typical fiber reinforced

Sample no.	Volume Fraction of fiber(%)	Experimental(MPa)	Theoretical(MPa)	Error (%)
1	0	30.15	30.15	DATUM
2	5	32.47	40.20	0.19
3	10	45.74	60.30	0.24
4	15	64.93	75.38	0.15
5	20	70.13	90.45	0.22

Table 4.4: Tensile strength comparison between experimental and theoretical value

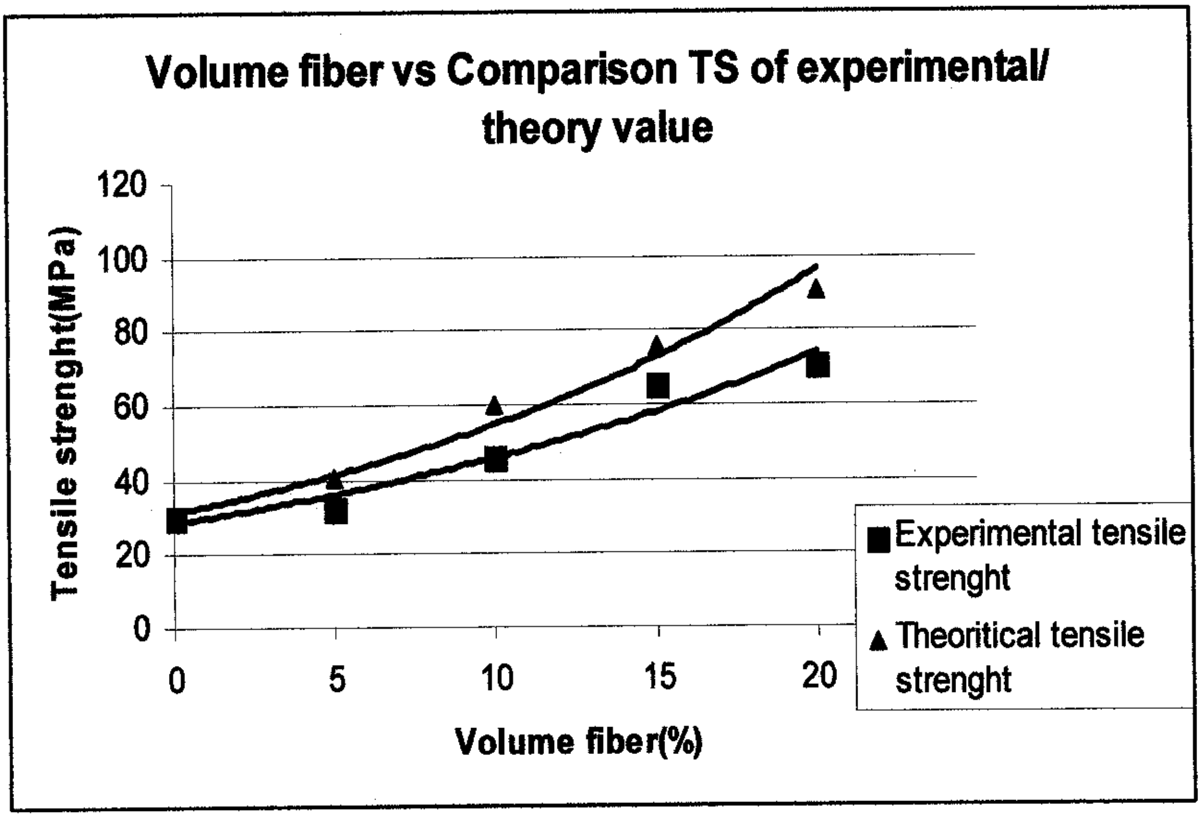


Figure 4.5: Graph of Tensile strength comparison between experimental and theoretical value

4.2 Property Prediction

	Carbon	Glass	Kevlar49
Tensile Strength (MPa)	4500	2600	2900
Modulus (GPa)	251	73	125
Density (g/cm^3)	1.8	2.5	1.45

Table 4.5: Resin Properties

	Polyester	Epoxy
Tensile Strength (MPa)	41.8	83.6
Modulus (GPa)	2.09	3.83
Density (g/cm^3)	1.1	1.2

Table 4.6: Fiber Properties

Using the rule of mixture (ROM), the properties of composite can be done. Table below show the predetermine properties of P-type and E-type composite.

1)P-TYPE COMPOSITE

a) Polyester/ Glass

Properties	Resin	Fibre	Fibre Volume fraction			
	(Polyester)	(Glass)	0.15	0.30	0.45	0.60
Tensile Strength (Mpa)	41.8	2600	425.53	809.26	1192.99	1576.72
Modulus (GPa)	2.09	73	12.73	23.36	34.00	44.64
Density (kg/m3)	1100	2500	1310	1520	1730	1940
Calculated Weight Fraction			0.29	0.49	0.65	0.77

Table 4.7: Properties of Polyester/Glass for P-type Composite

c) Polyester/Carbon

Properties	Resin (Polyester)	Fibre (Carbon)	Fibre Volume fraction			
			0.15	0.30	0.45	0.60
Tensile Strength (Mpa)	41.8	4500	710.53	1379.26	2047.99	2716.72
Modulus (GPa)	2.09	251	39.43	76.76	114.10	151.44
Density (kg/m3)	1100	1800	1205.00	1310.00	1415.00	1520.00
Calculated Weight Fraction			0.22	0.39	0.55	0.69

Table 4.8: Properties of Polyester/NWF Glass for P-type Composite

c) Polyester/Kevlar49

Properties	Resin (Polyester)	Fibre (Kevlar49)	Fibre Volume fraction			
			0.15	0.30	0.45	0.60
Tensile Strength (Mpa)	41.8	2900	470.53	899.26	1327.99	1756.72
Modulus (GPa)	2.09	125	20.53	38.96	57.40	75.84
Density (kg/m3)	1100	1450	1152.50	1205.00	1257.50	1310.00
Calculated Weight Fraction			0.19	0.36	0.52	0.66

Table 4.9: Properties of Polyester/Kevlar49 for P-type Composite

2)E-TYPE COMPOSITE

a) Epoxy/Glass

Properties	Resin (Epoxy)	Fibre (Glass)	Fibre Volume fraction			
			0.15	0.30	0.45	0.60
Tensile Strength (Mpa)	83.6	2600	461.06	838.52	1215.98	1593.44
Modulus (GPa)	3.83	73	14.21	24.58	34.96	45.33
Density (kg/m3)	1200	2500	1395.00	1590.00	1785.00	1980.00
Calculated Weight Fraction			0.27	0.47	0.63	0.76

Table 4.10: Properties of Epoxy/Glass for E-type Composite

b) Epoxy/Kevlar49

Properties	Resin (Epoxy)	Fibre (Kevlar49)	Fibre Volume fraction			
			0.15	0.30	0.45	0.60
Tensile Strength (Mpa)	83.6	2900	506.06	928.52	1350.98	1773.44
Modulus (GPa)	3.83	125	22.01	40.18	58.36	76.53
Density (kg/m3)	1200	1450	1237.50	1275.00	1312.50	1350.00
Calculated Weight Fraction			0.18	0.34	0.50	0.64

Table 4.11: Properties of Epoxy/Kevlar for E-type Composite

c) Epoxy/Carbon

Properties	Resin (Epoxy)	Fibre (Carbon)	Fibre Volume fraction			
			0.15	0.30	0.45	0.60
Tensile Strength (Mpa)	83.6	4500	746.06	1408.52	2070.98	2733.44
Modulus (GPa)	3.83	251	40.91	77.98	115.06	152.13
Density (kg/m3)	1200	1800	1290.00	1380.00	1470.00	1560.00
Calculated Weight Fraction			0.21	0.39	0.55	0.69

Table 4.12: Properties of Epoxy/Carbon for E-type Composite

All calculations above are in the longitudinal directions.

Rule of Mixture is $\mathbf{X_c = X_f V_f \times X_m(1\text{-}V_f)}$

Weight Fraction is $\mathbf{(P_f/P_c)^* V_f}$ **or** $\mathbf{W_f/W_c}$

Sample calculation for P-type composite

From Table a)

$E_c \quad = E_f V_f \times E_m(1\text{-}V_f)$

$E_c \quad = (73 \times 0.15) + (2.09 \times 0.85)$

$E_c \quad = 12.73$ GPa

Sample calculation for E-type composite

From Table a)

$E_c \quad = E_f V_f \text{ x } E_m(1\text{-}V_f)$

$E_c \quad = (73 \text{ x } 0.15) + (3.83 \text{ x } 0.85)$

$E_c \quad = 14.21 \text{ GPa}$

From the table above, it can be seen that the property of the composite is depending on the volume fraction that was used. It also indicates that the mechanical property of the composite is increased with an increment of the volume fraction fabrics for both polyester and epoxy based composites.

4.3 Construction Analysis

4.3.1 Thickness Calculation

The author may want to know the thickness of laminate for given amount of fiber and resin. The calculation for 20 cm x 20 cm polyester/glass (WF) composite with 15% volume fraction (29% weight fraction) as follow:

From specimen preparation calculation, it is found that

Resin weight = 39.95 g

Fiber weight = 16.35 g

Fiber area density for 29% WF $= 408\frac{g}{m^2}$

So, composite area density $= \frac{408}{0.29}$

$$= 1406.9\frac{g}{m^2}$$

Finally, the area density for resin $= 1406.9 - 408$

$$= 998.9 \frac{g}{m^2}$$

So, the thickness calculation is done by considering the area density of resin and fiber

$$\text{Since Thickness} = \left(\frac{\text{Area Density}}{\text{Density}}\right)$$

a) Thickness attributed by Fiber

$$\text{Thickness} = \left(\frac{\text{Fiber Area Density}}{\text{Density}}\right)$$

$$= 408 \frac{g}{m^2} \;/\; \frac{1m^3}{2500kg} \frac{1kg}{1000g}$$

$$= 1.632x10^{-4} m$$

$$= 0.1632mm$$

b) Thickness attributed by resin

$$\text{Thickness} = \left(\frac{\text{Resin Area Density}}{\text{Density}}\right)$$

$$= 998.9 \frac{g}{m^2} \;/\; \frac{1m^3}{1100kg} \frac{1kg}{1000g}$$

$$= 9.08x10^{-4} m$$

$$= 0.908mm$$

So the total thickness is, $= 0.908 + 0.1632$

$= 1.07$ mm (1 layer)

From this calculation, the author knows the thickness that has been contributed by resin and fiber. So that the author can choose how much layer that he wants so that the desired thickness can be achieved.

4.4 Discussion

Tensile strength (TS) can be referred as maximum engineering stress, in tension, that may be sustained without fracture. This corresponds to the maximum stress that can be sustained by a structure in tension; if this stress is applied and maintained, fracture will result.

From the results obtained in the mechanical testing and predetermined properties above, the author realized about the effect of increased the fiber volume fraction over the mechanical properties of composite. For example, from tables and graphs above it can be seen that, as an example the tensile strength of the composite with 30% of fiber is low compared to the composite with 45% of fiber volume. This shows that the mechanical properties are linearly increased when the fiber volume fraction is increased.

This happened because the composite have an extra tensile strength when fiber is introduced in the composite. The fiber itself has high tensile strength whereas the matrix has less tensile strength. Yet, by reinforcing those two will result a higher tensile strength, as the fiber will 'take place' for tensile properties position. The bonding between glass fiber and the resin will result a greater tensile strength.

Another parameter that will affect the mechanical properties of glass fiber is abrasion. Abrasion could happen by only rubbing the glass fiber with other material. In the project, it is obviously that the fiber is rubbing with the resin system during the laminating process. This action was taken because the author wants the mixture to be distributed homogenously. Thus, it is recommended that the glass fiber and the resin should be compounded first by using the extrusion machine. This will prevent the glass fiber and resin to rub with each other too much in order to decrease abrasion.

Last but not least, it is believed that the bonding between glass fiber and the resin is not enough. This bonding will decrease the tensile strength of the composite. It also believed that the bonding strength of the composite is different from one part to another. Thus, it is recommended that a coupling agent is needed to mix with reinforced fiber for bonding strength purpose. This will be a future work plan related to this project.

The specimen preparation must be done correctly so that the composite with desired volume fraction can be achieved. We also can see that the amount of the resin and fiber used is dependent on the volume fraction that we used.

From the thickness calculation, the author can see that both resin and fiber play important role in the thickness of the fabricated composite. Another number of layers can be introduced if the thickness is not quite enough.

Apart from that, based on the tables shown in Property Prediction section, it can be simply concluded that carbon fiber should be the best material for the car fabrication. Nevertheless, the study has shown that fiber glass is chosen as the material for the car external body after considering the cost factor. Although Kevlar49 and carbon fiber have shown greater compatibilities over the fiber glass in terms of the tensile strength, but both of it do not comply with the cost requirement. . It is found that the cost of the fiber glass is RM 30/m^2, RM 300/m^2 for the carbon fiber fabric and RM 80/m^2 for the Kevlar49.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Basically, the design team has decided to use the fiber glass as the material for the vehicle body due to its characteristics which have fulfill certain requirements especially the lightweight and cost factor. Apart from that, certain manufacturing processes such as the adhesive bonding, mechanical bonding and welding would be applied during the construction of the body part. In fact, the methodology for the body styling and fabrication has been identified which will be practiced for next step of the project.

This project is based on the existing car act as the main point of reference and all the design as based on the upgrading the car performance by having an aerodynamic shape and also considering the material used. Basically it is going to be a lightweight material that can exceed the limitation of the typical hybrid vehicle.

From the results, the predetermine properties of the composite showing the increased linearly with the increased of the fiber volume fraction. In this early phase of project, the author has seen the effect of mechanical properties that the composite can exhibits. After this, it is recommended that the project shall proceed with the development of the composite and hybrid composite and the testing can be done on this composite so that the mechanical properties of composite can be study and analyze more closely.

In addition to that, further co-operations should be developed with other research institutes or universities in order to get the objective of manufacturing a HEV becomes a reality. The Faculty of Mechanical Engineering of Universiti Teknologi Malaysia (UTM) and Universiti Tenaga Nasional (UNITEN) are among possible universities that University Technology PETRONAS (UTP) should consider working with in terms of the development of the manufacturing of composite external body for external body. Both universities mentioned above have enormous experiences in developing composite body solar cars through the utilization of their good facilities and sufficient human work force.

Form the lab work that has been done, the author now realized about the important of the specimen preparation since it affects the composite content and that is why the specimen preparation must be done correctly according to the desired volume fraction.

From the calculation, the author also knows about the thickness calculation for the composite and hybrid composite. This construction analysis is important since it can tell us about the thickness of fabricated composite. To get desired thickness, various numbers of layers can be introduced to the composite.

As a conclusion, the author knows about the materials that are going to be used for this project. The author also will work on the construction analysis and predetermines properties of composite. Then the manufactured composite can be produced by using the hand lay-up process, which has been selected as the manufacturing process for this composite. Finally, the testing phases that follow the standard can be done on the composite in order to study the mechanical properties of this composite and hybrid composite.

REFERENCES

- Happian-Smith, Julian, 2002, ***An Introduction to Modern Vehicle Design***, UK, Butterworth-Heinemann

- Larsen, R.P, 1995, **1994** ***Hybrid Electric Vehicle Challenge***, USA, Society of Automotive Engineers

- James A. Quinn, ***Composite Design Manual***, Lancaster, Technomic Publishing Company. 1999

- Michael S. Found, ***Experimental Techniques and Design in Composite Material 4***, Sheffield, UK, A.A. Balkema Publishers. 2002

- R.J Crawford, ***Plastic Engineering 2nd Edition***, Belfast, UK, Pergamon Press. 1998

- Sanjay K. Mazumdar, PhD, ***Composite Manufacturing (Materials, Products and Process Engineering)***, New York, CRC Press. 2001

- Daniel Gay, Suong V. Hoa, Stephen W. Tsai, ***Composite Materials Design and Application***, New York, CRC Press. 2003

- http://www.hypercar.com

- http://www.imhotep.ltd.uk/tp_matrix.html

- http://www.elsevier.com/locate/CompositesOnline

- http://www.polymers.com/

APPENDIX A

PROJECT MILESTONE FOR FIRST AND SECOND SEMESTER OF FINAL YEAR PROJECT

No.	Detail	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SW	EW
1	Selection of Project Topic																
2	Problem Definition & Design Goals																
3	Literature Review & Supplier Identification																
4	Submission of Preliminary Report																
5	Design Concepts & Analysis																
6	Economic Analysis/Budget																
7	CFD Modeling & Simulation																
8	Submission of Progress Report																
9	Wind Tunnel Testing																
10	Submission of Interim Report Final Draft																
11	Preparing Final/complete design																
12	Submission of Interim Report																

Project Milestone for First Semester of Final Year Project

No.	Detail	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SW	EW
1	Literature Review & Supplier Identification																
2	Submission of Progress Report 1																
3	Design Concepts & Analysis																
4	Economic Analysis/Budget																
5	CFD Modeling & Simulation																
6	Submission of Progress Report 2																
7	Wind Tunnel Testing																
8	Submission of Dissertation Report Final Draft																
9	Preparing Final/complete design																
10	Submission of Dissertation Report																
11	Oral Presentation																

Project Milestone for Second Semester of Final Year Project

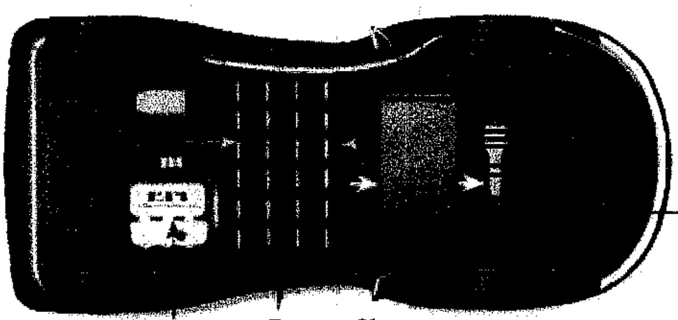
APPENDIX B

SERIES CONFIGURATION OF HYBRID ELECTRIC VEHICLE

An HEV with a series configuration uses the heat engine or fuel cell with a generator to produce electricity for the battery pack and electric motor. Series HEVs have no mechanical connection between the hybrid power unit and the wheels; this means that all motive power is transferred from chemical energy to mechanical energy, to electrical energy, and back to mechanical energy to drive the wheels. Here are some benefits of a series configuration:

- The engine never idles, which reduces vehicle emissions.
- The engine drives a generator to run at optimum performance.
- The design allows for a variety of options when mounting the engine and vehicle components.
- Some series hybrids do not need a transmission.

The downside is that series HEVs require larger, and therefore, heavier battery packs than parallel vehicles. In addition, the engine works hard to maintain battery charge because the system is not operating in parallel.



APPENDIX C

APPENDIX B

SERIES CONFIGURATION OF HYBRID ELECTRIC VEHICLE

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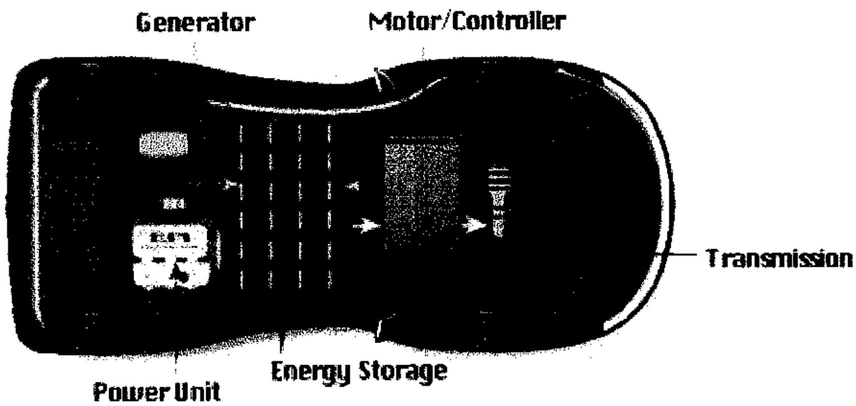
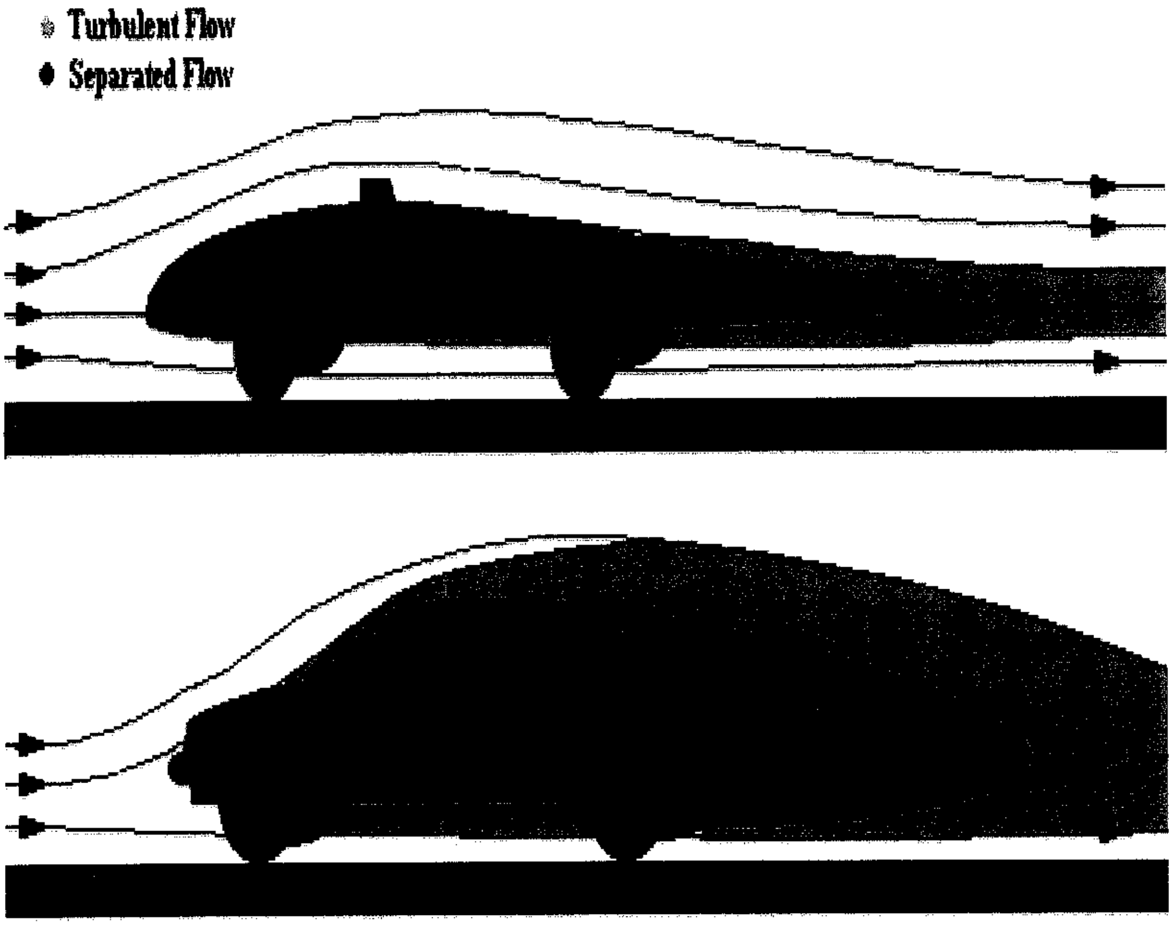


APPENDIX C

COMPARISON BETWEEN TURBULENT FLOW AND SEPARATED FLOW

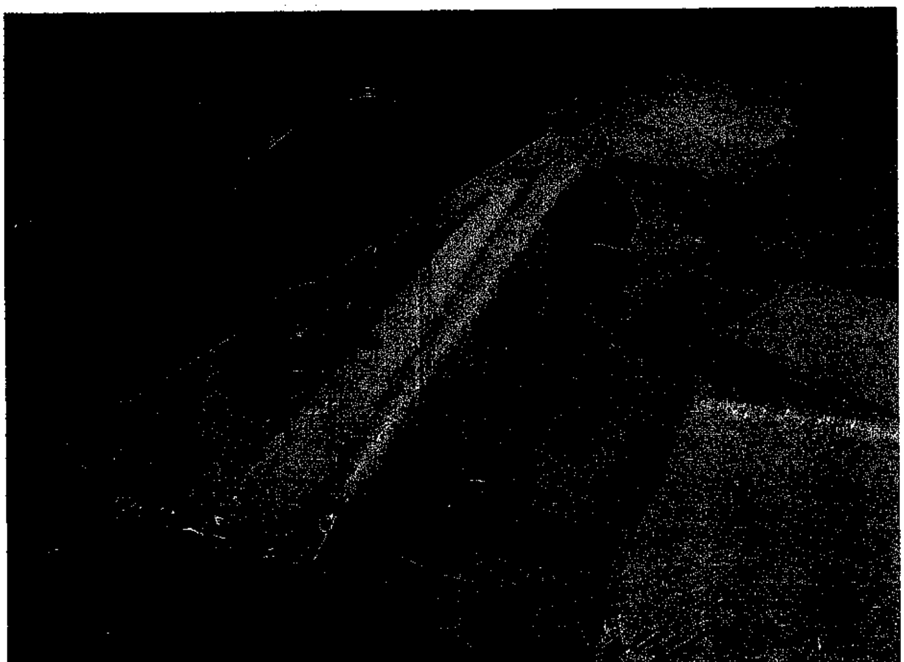


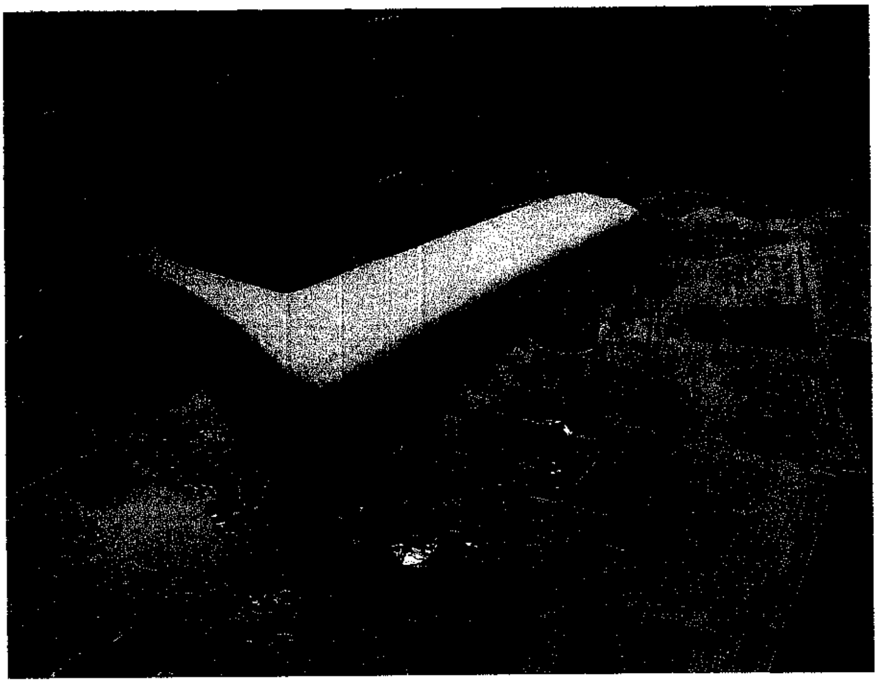
Comparison of conventional and aerodynamic car that can cause different set of wind flow upon the surface due to the design structure.

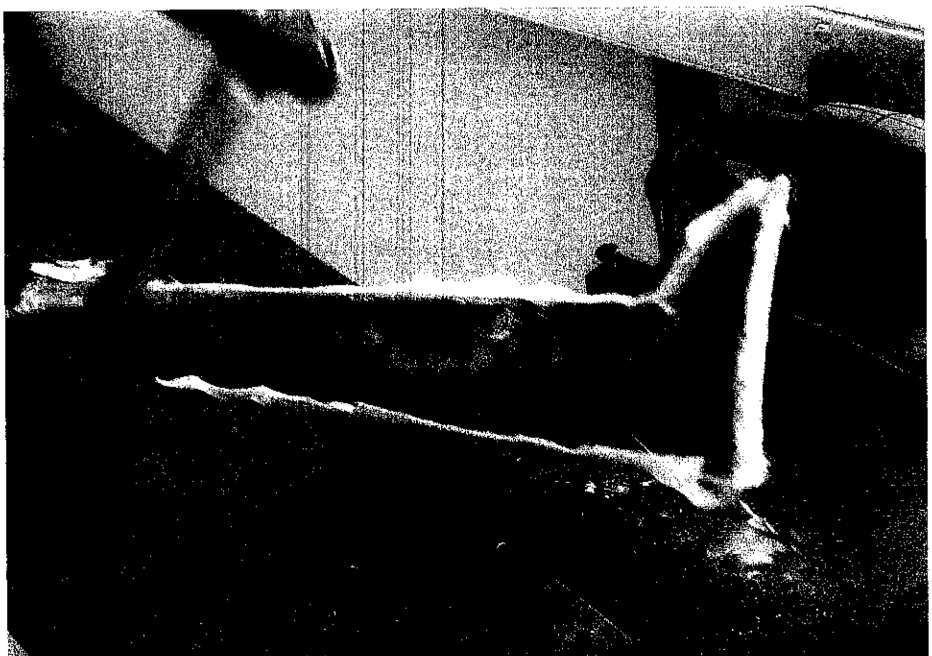
Cyan shaded areas indicate turbulent air that has been slowed but is still flowing downstream. Red shaded areas indicate highly turbulent air flowing upstream, known as separated flow. The solar car had only small areas of this behind the wheels.

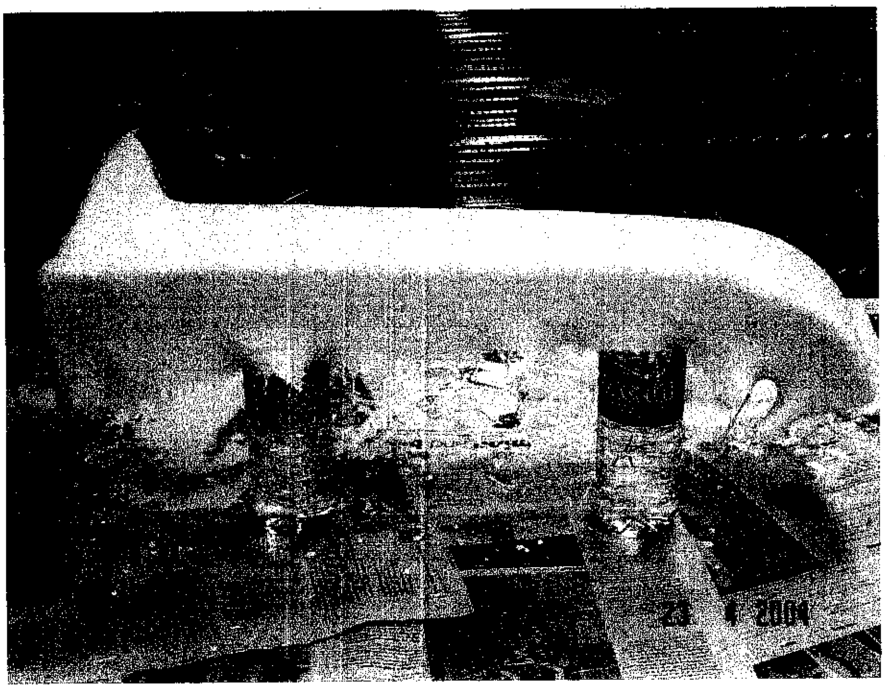
APPENDIX D

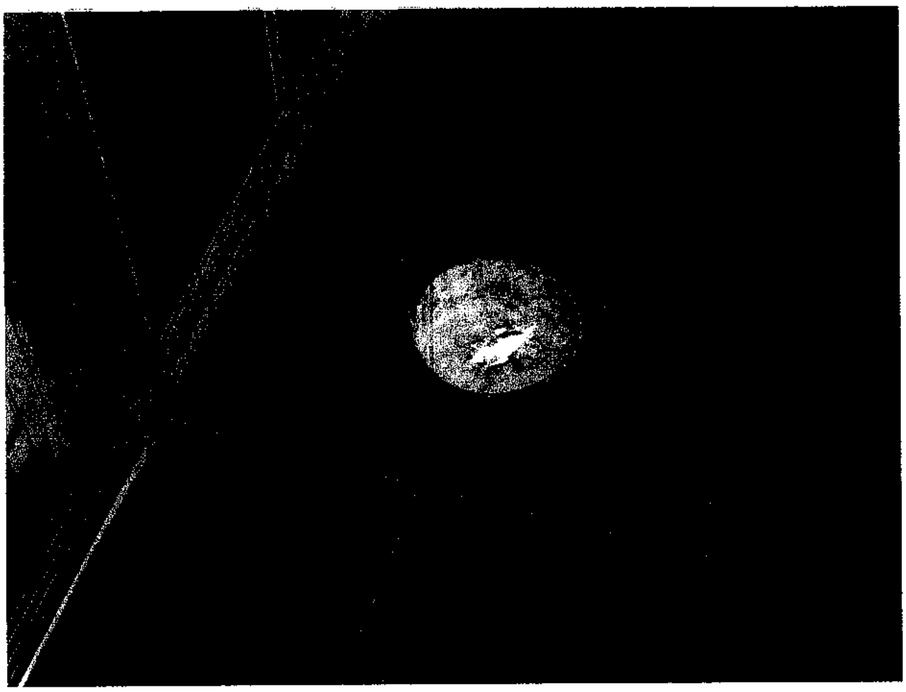
IMAGES OF LABORATORY WORK (FABRICATION OF CAR PART BY USING HAND-LAY UP TECHNIQUE)











APPENDIX E

IMAGES OF MECHANICAL TESTING (TENSILE TEST) OF SHORT FIBER AND POLYPROPYLENE COMPOSITE

MATERIAL PROPERTIES

Below are the properties of composites used and fiber glass.

Glass Fiber Properties (E-Glass):		
Density (Mg/m^3)	-	2.56
Young's Modulus (Gpa)	-	70
Tensile Strength (Mpa)	-	2200
Melting Point (^oC)	-	550

Figure D1: Short glass fiber used in the project

Polypropylene Properties:

Density (Mg/m^3)	-	0.9
Young's Modulus (Gpa)	-	1.3-1.8
Tensile Strength (Mpa)	-	25-38
Melting Point (^oC)	-	165

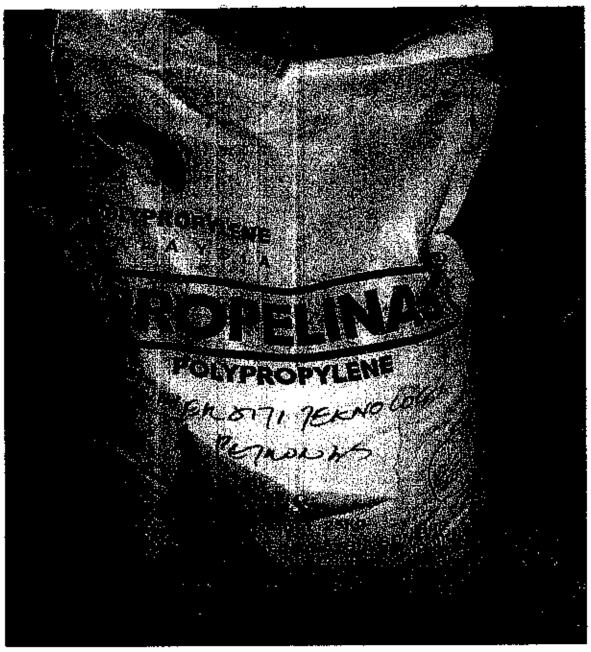


Figure D2: Polypropylene used in the project

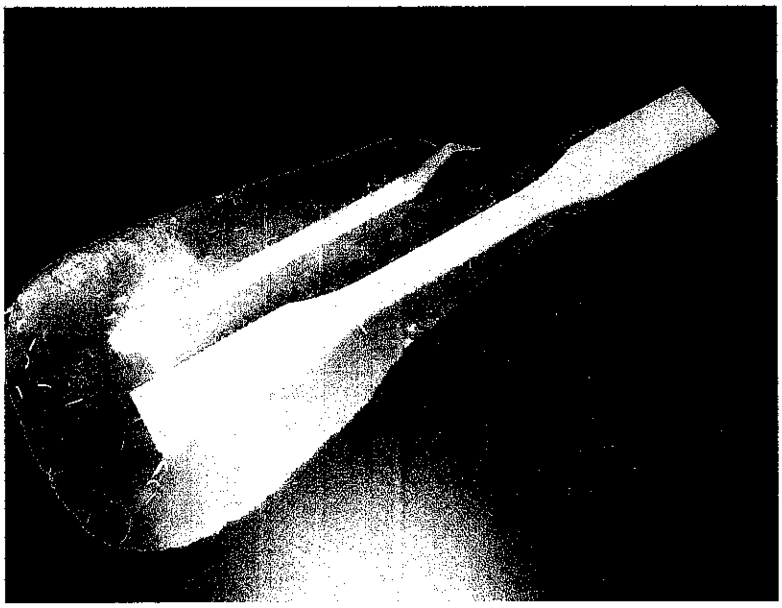


Figure D3: Molded Fiber reinforced using polypropylene and 5% of volume fiber

Weight of composite(kg)		5
Density(kg/m^3)	Polypropylene	900
	Short fiber	2560

Table D1: Density of short fiber and polypropylene in the project.

Fiber Vol. Fraction(%)	Weight of short fiber, W_f(kg)	Weight of polypropylene, Wpp(kg)
5	0.615	4.385
10	1.143	3.857
15	1.600	3.400
20	2.000	3.000

Table D2: Weight estimation for polypropylene and short fiber

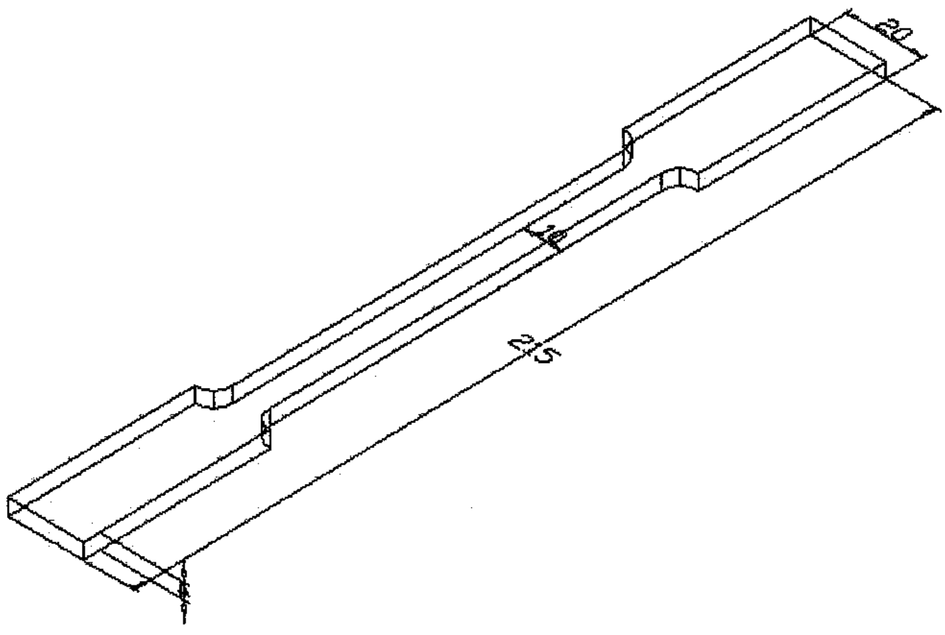


Figure D4: The dog bone-shaped specimen dimension in millimeter unit.

Figure D4: Injection molding machine