DESIGN AND ANALYSIS OF THE SOLAR CAR BODY

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Report submitted in partial fulfillment of the requirements

for the award of Diploma in Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2010

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS

JUDUL: **DESIGN AND ANALYSIS OF THE SOLAR CAR BODY**

SESI PENGAJIAN: 2010/2011

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I hereby declare that I have checked this project report and in my opinion this project is satisfactory in terms of scope and quality for the award of Diploma in Mechanical Engineering.

Signature : …………………………….

Name of Supervisor : MOHAMED REZA ZALANI BIN MOHAMED SUFFIAN

Date : 24 NOVEMBER 2010

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ACKNOWLEDGEMENTS

Alhamdulillah, I would like to express my thankfulness to Allah s.w.t to giving me all the strength in fulfilling and completely this final year project. All the praise and blessing be upon prophet Muhammad s.a.w. I would like to thank to those who had been involved whether directly or in directly in helping me to complete my final year project. It could not have been written and produced without the help of many people.

Special appreciated is extended to Mohamed Reza Zalani Bin Mohamed Suffian who acts as my supervisor. Thank for supervision and encouragements. I also would like to all my friend who always been listening my problems during the period to finish this dissertation. All your kindness is very much appreciated.

I sincerely grateful to my parents for they love and sacrifice that they had for me throughout my life and their support for me in all my activities that I have done. I also wanted to that other people who have directly or indirectly help in the completion of my Final Year Project. I sincerely appreciate all your help.

ABSTRACT

This report shows the design and analysis of body parts for racing solar cars because this play an important role in the motor industry today and solar car also powered by sun energy (solar). This is obtained from solar panels on the surface of the vehicle. Photovoltaic (PV) cells convert the sun's energy directly into electric energy. This is project use the materials type as carbon fiber. Overall, this project involves many processes, starting from the design concept, in this project design is very long time and this part most important in solar car industry. Secondly start the analyzing the parts of the body because the body plays a role in absorbing solar energy as possible as well, the car body design aerodynamic.

ABSTRAK

Laporan ini memaparkan reka bentuk dan menganalisis bahagian tubuh kereta solar untuk tujuan perlumbaan, kerana ini memainkan peranan penting dalam industri permotoran masa kini dan kereta solar juga dijana oleh tenaga matahari (solar). Tenaga solar ini diserap oleh panel suria pada permukaan kenderaan. Sel photovoltaic (PV) menukarkan tenaga solar menjadi tenaga elektrik. Projek ini menggunakan bahan jenis serat karbon. Secara keseluruhan, projek ini melibatkan banyak proses, mulai dari konsep mereka bentuk, masa untuk mereka bentuk projek adalah waktu yang sangat panjang dan ini bahagian paling penting dalam industri kereta suria. Yang kedua, memulakan menganalisis di bahagian tubuh, kerana bahagian tubuh memainkan peranan dalam menyerap tenaga suria sebanyak mungkin disamping, mereka bentuk tubuh kereta yang aerodynamik.

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CHAPTER 1

INTRODUCTION

1.1 PROJECT SYNOPSIS

The project contains of the designing and analysis of the solar car body for race. There have a many differences between this of the design body of solar car with current design in the world. This project is to develop and improving it performance as well so that there has no doubt about the design and concept. In this project, it needs lot of skills and information, research and also knowledge such as Computer Aided Design Software (Auto Cad), Solid works software and knowledge in automotive industries and solar industry.

This project must combine a technology typically used in the aerospace, bicycle, attentive energy, solar industries and automotive industries. So this design solar cars have been built for the purpose of solar car races only.

1.2 PROJECT PROBLEM STATEMENT

i. Shaping the vehicle body to allow solar cells to receive more solar energy.
ii. Maximum speed for solar car race.
iii. Design the car body with the aerodynamic.

1.3 PROJECT OBJECTIVES

1.3.1 General objective

Diploma final year project objectives is to practices the knowledge and skill of the student that have been gathered before solving problem using academic research, to born an engineer that have enough knowledge and skill. This project also to complete the subject on this semester. The student also can be explore the advanced machine before involves in industries. The project otherwise will be produce and train student capable of doing word with minimal supervisor and moray independent in searching, detailing and expending the knowledge and experiences. The project also will generate student that have capability to make a good research report in thesis form technical writing.

1.3.2 Specific project objective

The main objectives of this project is to design and analysis the solar car body for racing that light in weight and high durability using solid word, and other software.

1.4 PROJECT SCOPE

i. Maximum driver's weight up to 75kg.
ii. The solar car have a three wheels only.
iii. Design body solar car for racing only
iv. Design of the body within 3.2m long, 1.2m wide and 0.8m high.

1.5 PROJECT PLANNING

This project is beginning with meet supervisor to collect information and otherwise search from via internet, books and survey at laboratory, this literature review must do for every week. The finding of information not will be stop on a week but continues along the way of this project because to get more information.

The Gantt chart (time management) and flow chart (process management) will be developing on second week. This is done using Microsoft Excel using Gantt chart system.

The fourth week the Pugh analysis and matrix analysis will be developing. The function of this analysis is to get a final design, from three design any criteria will be research to get good concept. After get a final design solid word will be start.

Just final design will use this software for analysis. Each part will be developed and lastly the assembly part will be begun.

On weeks sixth and seventh the progress report will be start. Meeting with supervisor on weeks seventh and ninth gather date to complete progress report. That week the mid presentation also start.

The analysis of aerodynamic will be start after mid presentation. The process of analysis for the body and bottom of solar car start on week eleventh. At the same time the prepare for the final presentation. The planning process of analysis around week's twelfth until fourteenth.

After finish the process analysis, the final report will be start. To complete the report it will use format thesis 2010. The last presentation will be started on week fifteenth.

ACTIVITIES	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title Selections.														
Proposal (background, objective, scope, problem statement)														
skecth & design selection on project and then discuss with supervisior														
Pre-presentation														
Analysis and Discussion														
Final report														
Final presentation														

Table 1.1: Gantt Chart

CHAPTER 2

LITERATURE VIEW

2.1 INTRODUCTION

Body design is an important criterion for race car. Race car body is particularly important in aerodynamic because have a reduces drag and hence provides smooth air flow along the race car. Also, the body design is analogous as an upside down wing, providing negative lift or down force for stability. Besides that, car body encloses the driver and all important components so that to protect him against any projectiles created by the race car in front. Lastly, car body is a major contributor in a race car appearance. A race car with eye-catching body always is an attraction in racing competition.

2.2 BODY OF SOLAR CAR

2.2.1 Introduction

The Solar car have a smaller amount of energy available compared to conventional engine passenger vehicles. The power is needed to overcome the resistance to motion. These resistances generally caused by rolling resistance and air resistance (aerodynamics).

It can be represented in the form of an equation as:

$$R = k_r\, m\, g + k_a\, A\, V^2$$

Where, k_r = Co-efficient of rolling resistance
m = Mass of vehicle
g = Gravity constant
k_a = Aerodynamic drag co-efficient
A = Forward drag co-efficient
V = Speed of vehicle

Hence, a well designed body or shell can reduce the air resistance on the car when it moves. Air resistance is referred to as aerodynamic drag. If a moving object is streamlined, the air will flow around it smoothly and cause less drag, therefore needed less energy to move the object. Beside that, one goal for the teams who design solar car is to achieve extremely low aerodynamic drag while still maintaining a suitable surface for the solar cells and adequate space for the driver and other component.

Some of Concept will be discussed is:

i. Aerodynamics

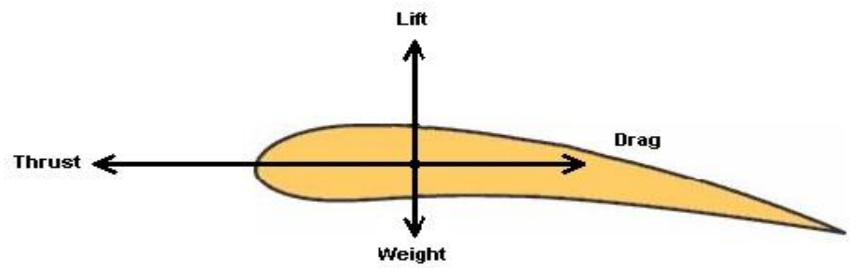

Figure 2.1: Forces on aerofoil shape

ii. Frontal Area

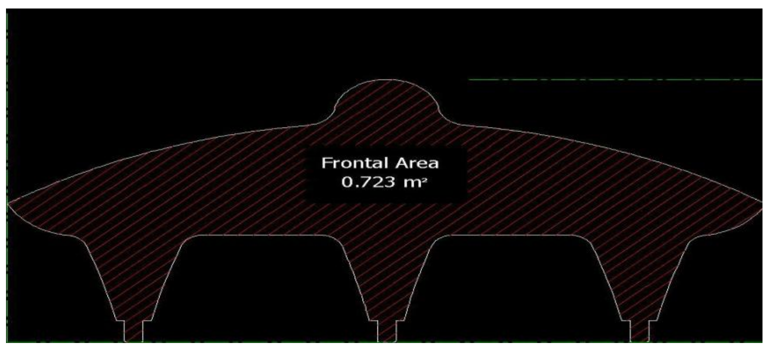

Figure 2.2: Frontal Area

iii. Shaping

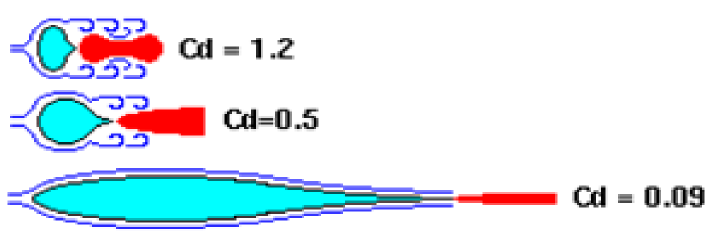

Figure 2.3: Affected of shape on C_d

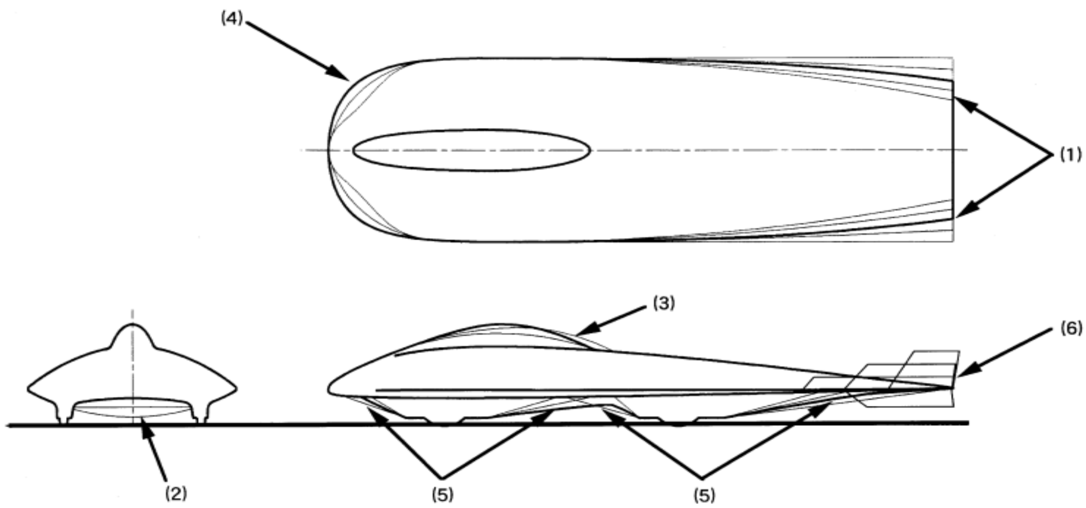

Figure 2.4: Model shape detail

2.2.2 Development of a solar car

The body of a solar car should be designed to optimize the balance of generating capacity of solar cells and aerodynamic performance in order to have the highest overall efficiency. Generating capacity will be increased by:

a. Shaping the vehicle body to minimize drag force
b. Increasing the area of solar cell installed on body
c. Shaping the vehicle body to allow solar cells to receive more solar energy.

2.2.3 Aerodynamic development

One goal for the teams who design solar cars, is to achieve extremely low aerodynamic drag while still maintaining a suitable surface for the solar cells and adequate space for the driver and the other components. Once a design is proposed, the shape should be tested to obtain figures for drag.

Testing proposed aerodynamic shapes is generally done in one of two ways. The first is to build scale models that are tested in a wind tunnel to simulate air flow across the car. The second is to use a powerful computer program that does the same kind of air flow simulation using a computer-generated model of the car.

One objective of aerodynamic studies is the design of shapes that offer the least resistance to the flow of air. Air offers a resistance to any object moving through it. Air resistance is influenced by the shape of an object. Aerodynamics engineers study the way in which air flows around objects, but it is still somewhat a black art.

Air resistance is referred to as aerodynamic drag. If a moving object is streamlined, the air will flow around it smoothly and cause less drag, therefore needing less energy to move the object. Such a design is considered to be aerodynamically efficient. When an object produces poor airflow, more energy is required to push it forward.

Aerodynamics also is the way air moves around things, under aerodynamic development have a two sections of the end, is;

a) Drag coefficient (C_d)

The drag coefficient (C_d) is a number that describes a characteristic amount of aerodynamic drag caused by fluid flow, used in the drag equation. Coefficients for rough unstreamlined objects can be 1 or more, for smooth object much less.

Generally C_d values come from test of shapes with known cross sectional area. These experiments will be done by use wind tunnels. The arrow in front of the shape gives the direction of the air blowing over the shape.

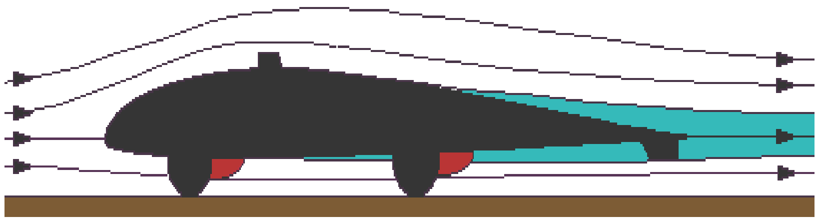

Figure 2.5: Slipstream Aerodynamic

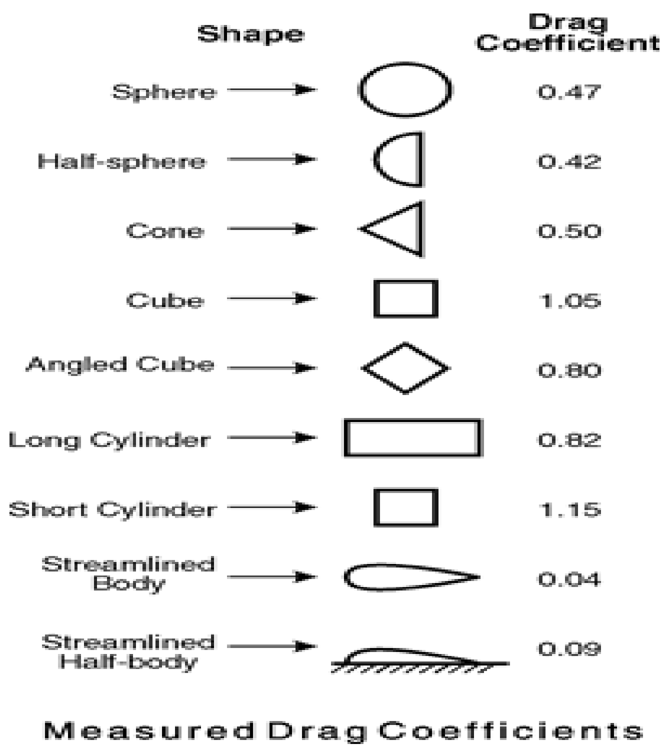

Figure 2.6: Drag coefficients for some basic shapes

b) Drag equation

The drag equation gives the drag force by an object moving through a fluid. This equation related to Cd, the drag coefficient; A, frontal are and the speed of air past it. This equation shows an important point – aerodynamics forces are proportional to the square of the speed. That means

$$D = \frac{1}{2}\rho v^2 A C_d$$

D	is the force of drag,
P	is the density of the fluid,
V	is the velocity of the object relative to the fluid,
A	is the reference area, and
C_d	is the drag coefficient

2.2.4 The Solar Car Array

The solar array is the vehicle's only source of power during the cross-country Rayce. The array is made up of many (often several hundred) photovoltaic solar cells that convert the sun's energy into electricity. Teams use a variety of solar cell technologies to build their arrays. The cell types and dimensions of the array are restricted by the Regulations, depending on the vehicle size and class.

The cells are wired together to form strings. Several strings are often wired together to form a section or panel that has a voltage close to the nominal battery voltage. There are several methods used to string the cells together, but the primary goal is to get as many solar cells possible in the space available. The solar cells are very fragile and can be damaged easily. Teams protect the cells from both the weather and breakage by encapsulating them. There are several methods used to encapsulate cells and the goal is to protect the cells while adding the least amount of weight.

The power produced by the solar array varies depending on the weather, the sun's position in the sky, and the solar array itself. On a bright, sunny day at noon, a good solar car solar array will produce well over 1000 watts (1.3 hp) of power. The power from the array is used either to power the electric motor or stored in the battery pack for later use.

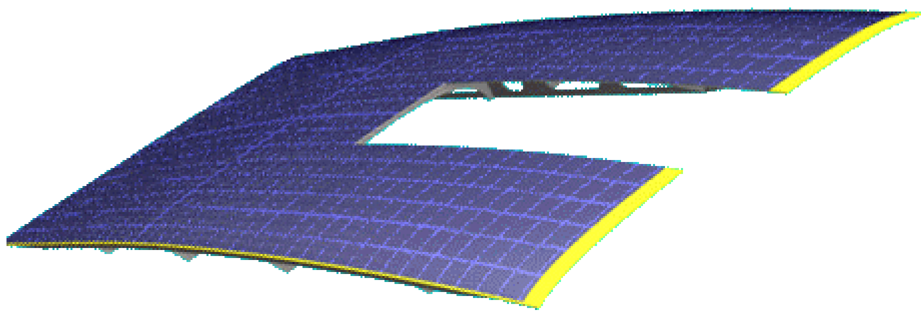

Figure 2.7: Solar Car Array - or cells arrangement

2.2.5 Type of Materials Selection

Carbon fiber was selected to make the whole solar car body by welding method and using special filler**.** For the characteristic the carbon fiber is following

- Carbon fiber: Physical strength, specific toughness, light weight. High dimensional stability, low coefficient of thermal expansion, and low abrasion, good vibration damping, strength, and toughness.

Mechanical Properties	
Elastic Modulus (MPa)	69000
Flexural Modulus (MPa)	34500
Tensile Strength (MPa)	276 - 345
Compressive Strength (MPa) at yield or break	207 - 276
Flexural Strength (MPa) at yield or break	518 - 656
Elongation at break (%)	1 - 2
Hardness	55 - 65
Izod Impact (J/cm of notch) 1/8" thick specimen unless noted	8.0 - 10.6

Table 2.1: Mechanical Properties for Carbon Fiber

Processing Properties	
Melting Temperature (ºC)	thermoset
Processing Temperature (ºC)	133 - 166
	133 - 166
Molding Pressure (MPa)	4 - 14
Compression Ratio	2
Linear Mold Shrinkage (cm/cm)	0.001

Table 2.2: Processing Properties for Carbon Fiber

Figure 2.8: Carbon Fiber Penal

2.3 FRAME AND CHASSIS

The most distinctive part of solar cars are the bodies. The sleek and exotic shapes are eye catching. Solar cars are grouped into several body classes, but every car is unique because there are no established standards, with the exception of dimensional constraints. The main goals when designing the body are to minimize the aerodynamic drag, maximize the exposure to solar insulation, minimize weight, and maximize safety. There are many theories on what body shape and size is the most efficient

The primary challenge in developing an effective solar car chassis is to maximize the strength and safety, but minimize the weight. Every extra pound requires more energy to move down the road. This means that we must minimize weight and a key area is the chassis. However, safety is a primary concern and the chassis must meet stringent strength and safety requirements.

Figure 2.9: Frame of solar car in university of Auburn (2003)

]

2.4 BOTTOM PART

In the case of an automobile, the term chassis can refer to the frame and to the "running gear" like engine, transmission, driveshaft, differential, and suspension. In our solar car project, we make 2 part for covering the chassis, there are upper part and bottom part.

The function of bottom part are to support a small part, to limited a turbulence, and as esthetic view. In this solar car project, the bottom part will attach with chassis and support the batteries, power tracker.

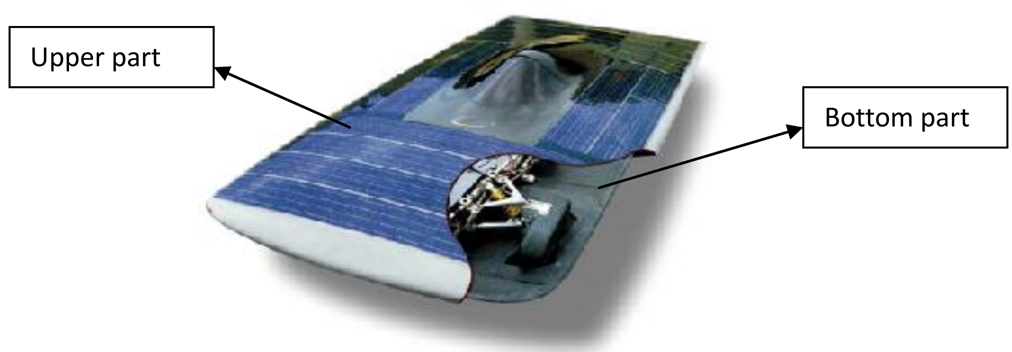

Figure 2.10: Bottom part in solar car

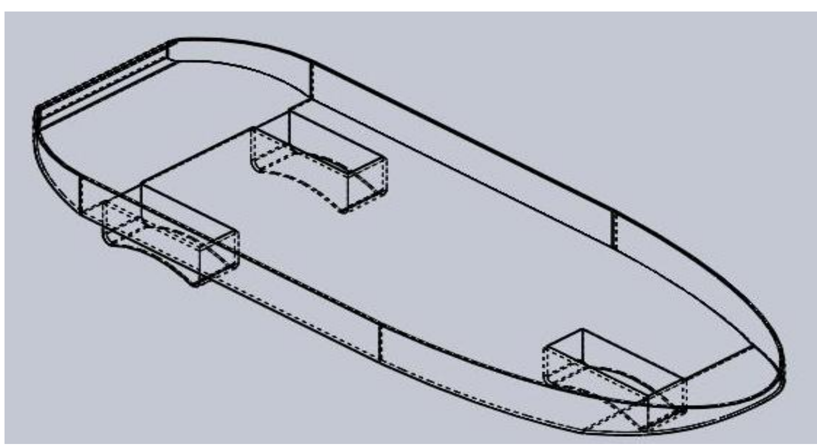

Figure 2.11: Bottom part for this Project

CHAPTER 3

METHODOLOGY

3.1 PROJECT FLOW CHART

From the flow diagram on Figure 3.1, this project started with discussion with supervisor about title after got from lecturer. This discussion covering project overview supervisor and throw out opinion that related about title and supervisor instruct to proposed a certain design and concept before go up to next step.

Then go to literature review about the title. The most important in these manner is a determined the project scope, objective and project planning so that could easy get a clear overview. Then study and gather information related to the design and these entire task been done through study from internet, journal and other source.

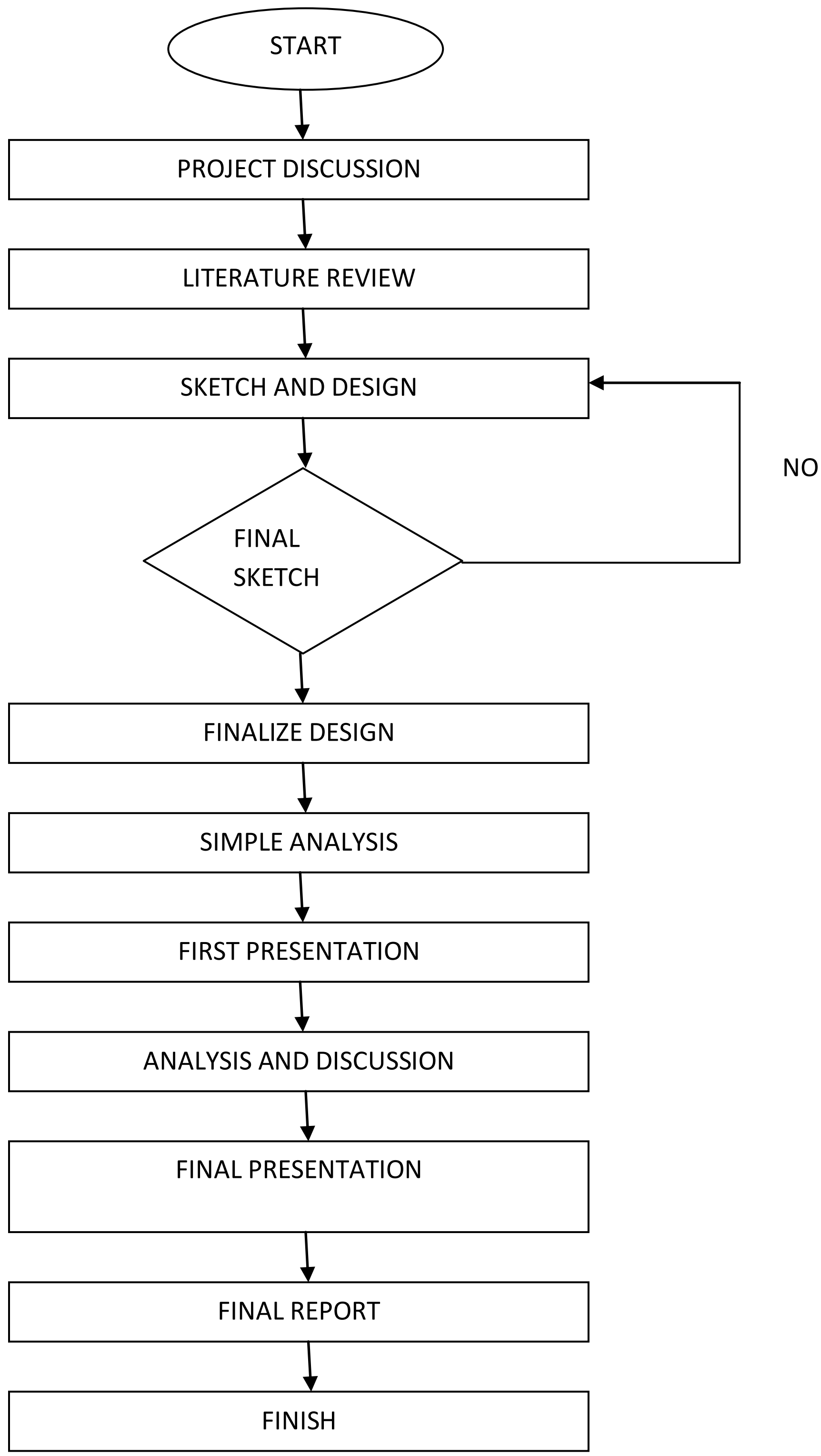

Figure 3.1: Flow chart of Project

3.2 DESIGN CONCEPT

3.2.1 Concept Design A

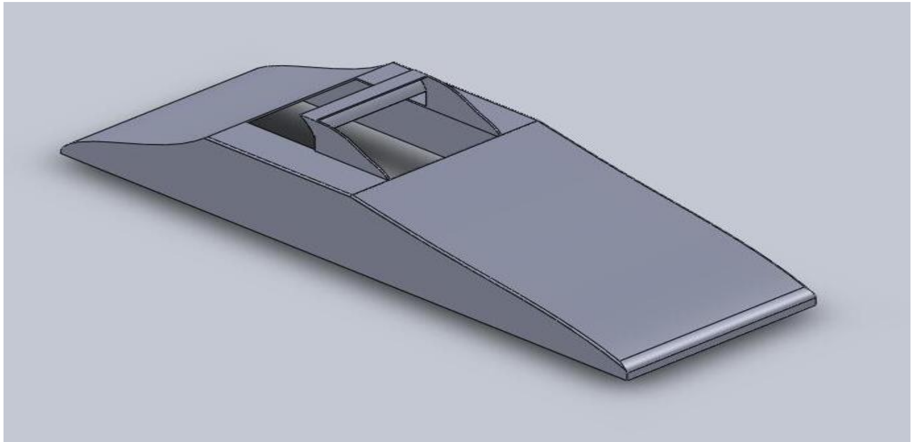

Figure 3.2: Concept Design A

3.2.2 Concept Design B

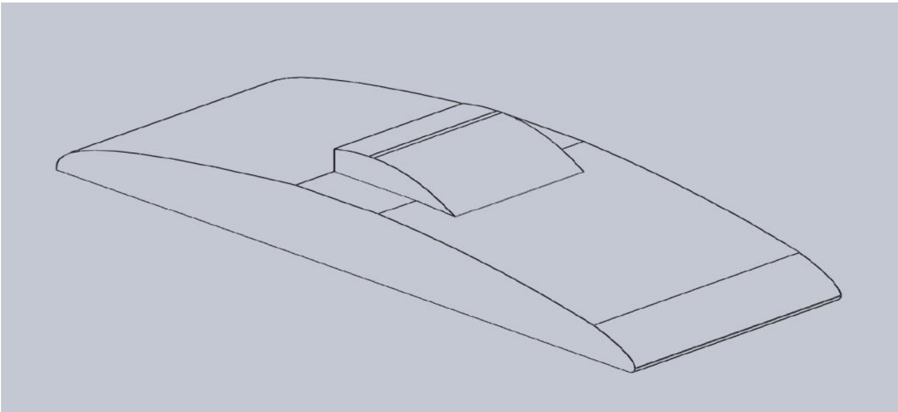

Figure 3.3: Concept Design B

3.2.3 Concept Design C

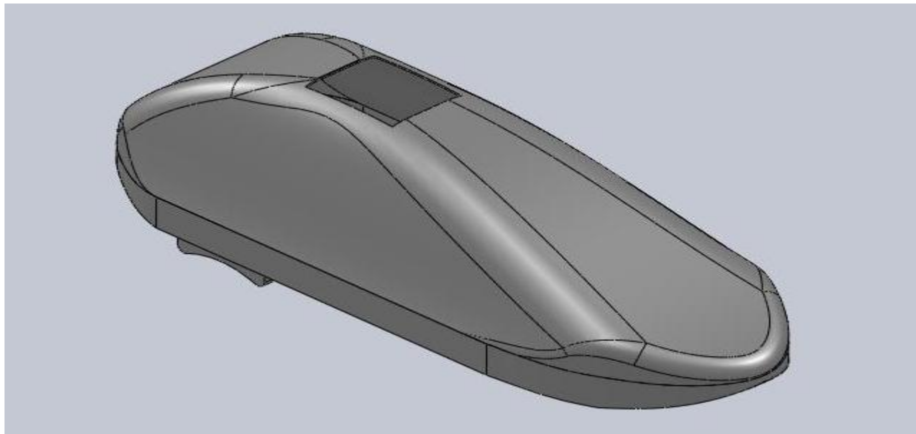

Figure 3.4: Concept Design C

3.2.4 Concept Design D

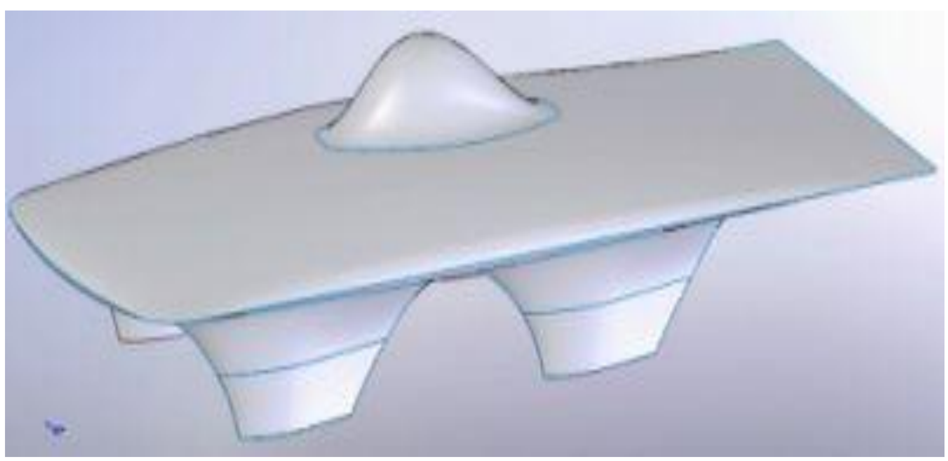

Figure 3.5: Concept Design D

3.3 CONCEPT GENERATION AND EVALUATION

The are ten criteria to be concerned in the effort to determine the best selection of design concept in a body of solar car rare

i. Aerodynamics
ii. Stability
iii. Weight
iv. Safety
v. Cost
vi. Installation
vii. Ergonomic
viii. Aesthetic
ix. Maximum speed drive

Weighting and Aerodynamic method is used to determine the relative important of the selected criteria. The method is used to enhance the process to Cary out the most optimum design.

Criteria	CONCEPT			
	Design 1	**Design 2**	**Design 3**	**Design 4**
Aerodynamics	(+)	0	(+)	(-)
Stability	(-)	0	0	(+)
Weight	0	(+)	(+)	(-)
More strength	0	0	0	(+)
Safety	0	0	0	0
Installation	(-)	(+)	(+)	0
Suitable cost	(-)	0	(+)	-
Easy fabrication	(-)	(+)	(+)	(+)
Suitable design (interesting)	(+)	0	0	0
Suitable size	0	0	0	0
Very good	2	3	5	3
Good	4	7	5	4
Not bad	4	0	0	3
Rank	4	2	1	3
Continues	NO	NO	**YES**	N0

Table 3.1: Concept Selection

3.4 FINALIZE DESIGN

Top view

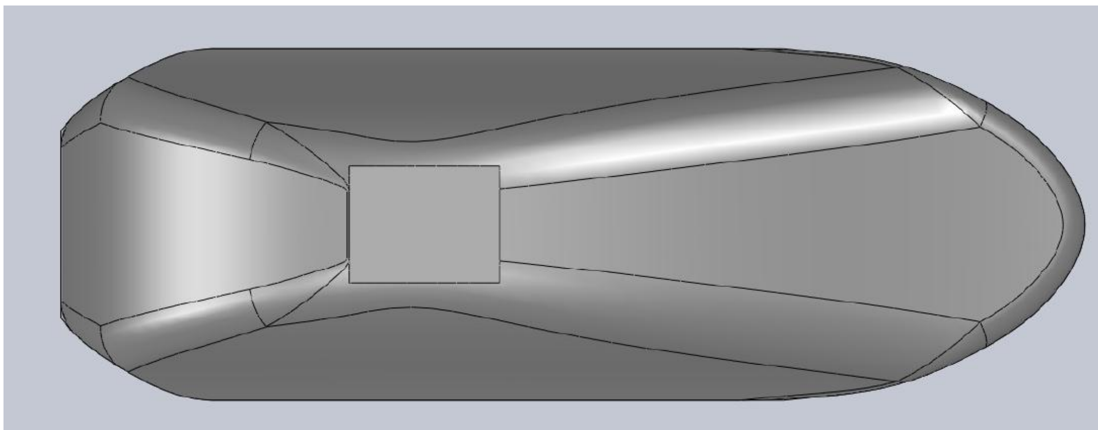

Figure 3.6: Top view of Body

Side view

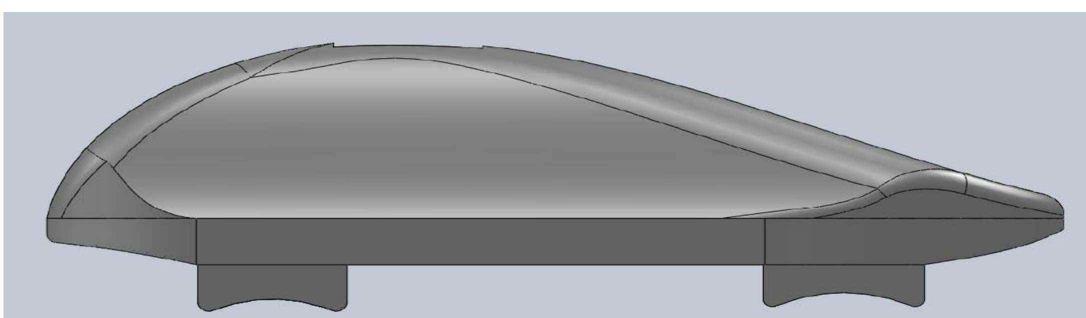

Figure 3.7: Side view of Body

Front view

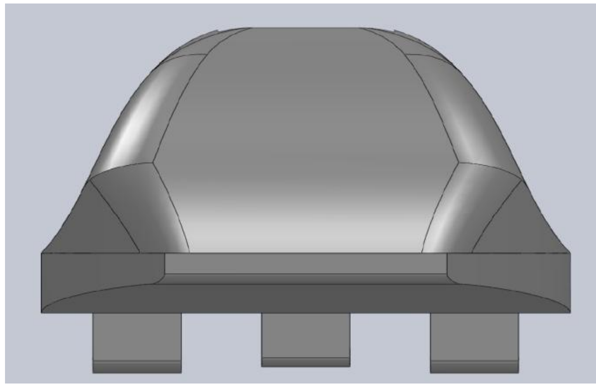

Figure 3.8: Front view of Body

Isometric view

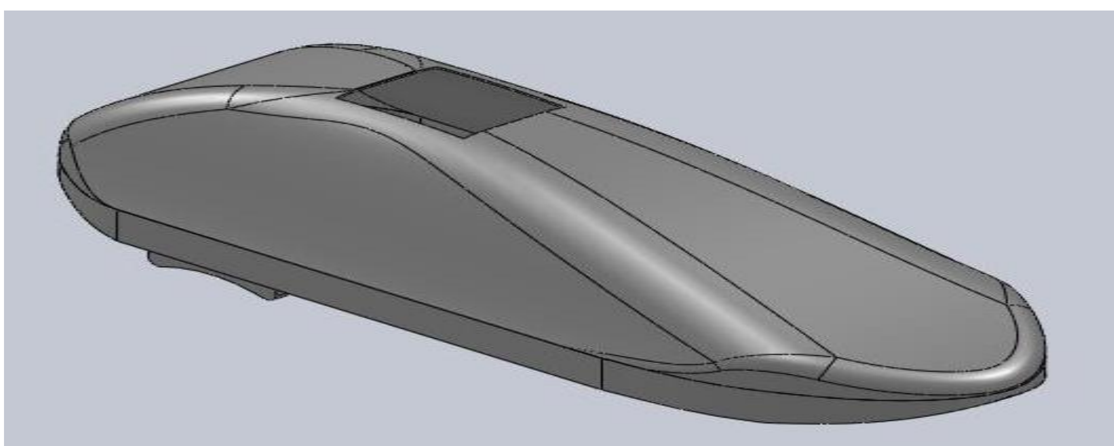

Figure 3.9: Isometric view of body

3.5 PRODUCT DESIGN SPECIFICATION

- Vehicle mass ~ 280 kg (with driver)
- Body part 35 kg
- Occupants 1 (driver)
- Car Length 3.2m
- Car Width 1.2m
- Car Height 0.80m
- Ground Clearance 0.40m
- Weight distribution 65% front, 35% rear
- Wheel track 1.2m
- Wheelbase 2.0m
- Frontal Area 0.723m^2

Parts	Weight	Type
Battery	25 Kg	Kokum Lithium Polymer, 130 volts 6P31S,
Seat	8 Kg	Molded fiberglass
Motor + controller	35Kg	Permanent magnet brushless DC (PM-BLDC) motor
Pilot	50Kg	-

Table 3.2: Parts weight

3.6 ENGINEERING DRAWING OF THE DESIGN

3.5.1 Upper part

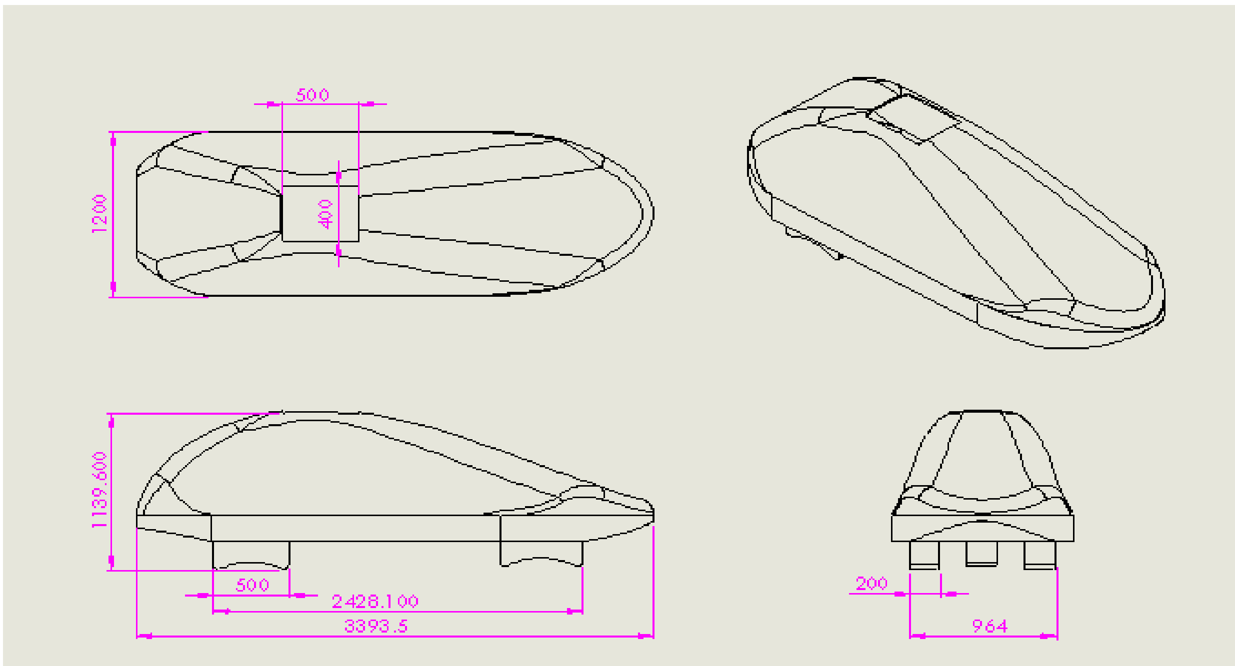

Figure 3.10: Design Upper Body in 3D drawing

3.5.2 Bottom part

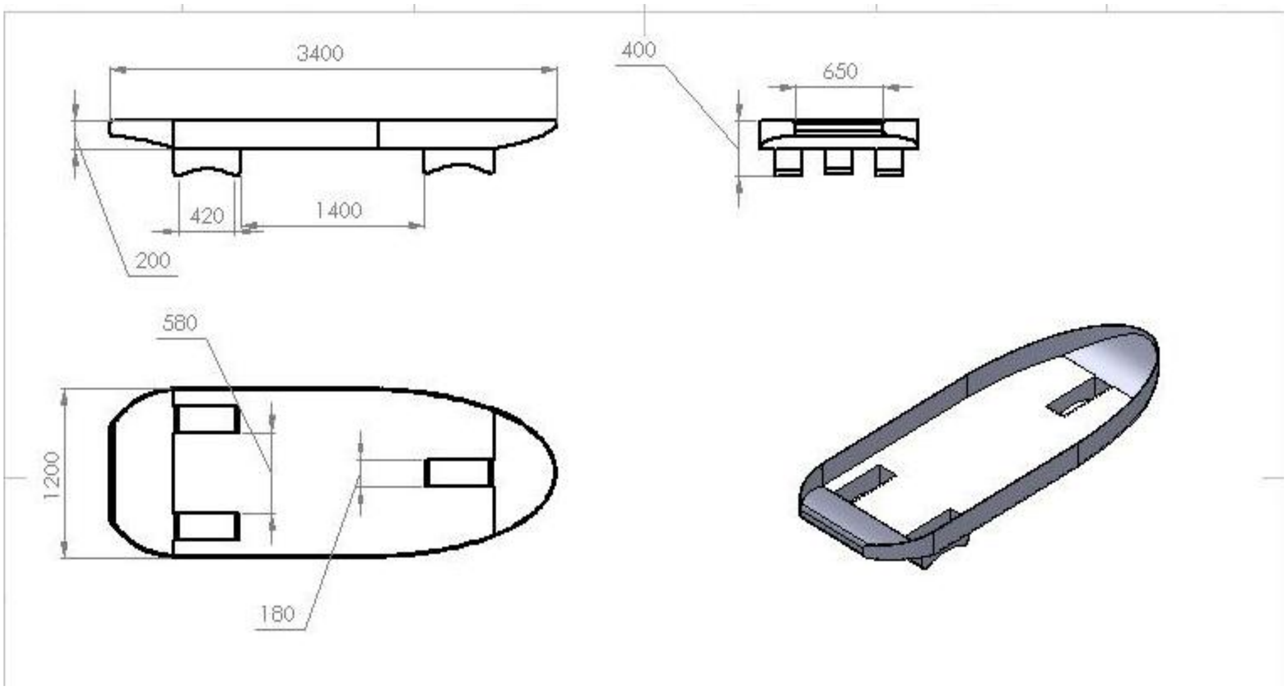

Figure 3.11: Design Bottom Body in 3D drawing

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

The project contains of the designing and analysis of the solar car body for race. So this chapter discuss of the results and analysis of the project after the selected of the design. For the analysis of the project, using the Solid Word, Auto Cad, and many research from the internet, journal, library, and the most references from the supervisor. The result is it maximum velocity of the air flow (streamline) and Forces on the bottom part.

4.2 RESULT

4.2.1 Body Part

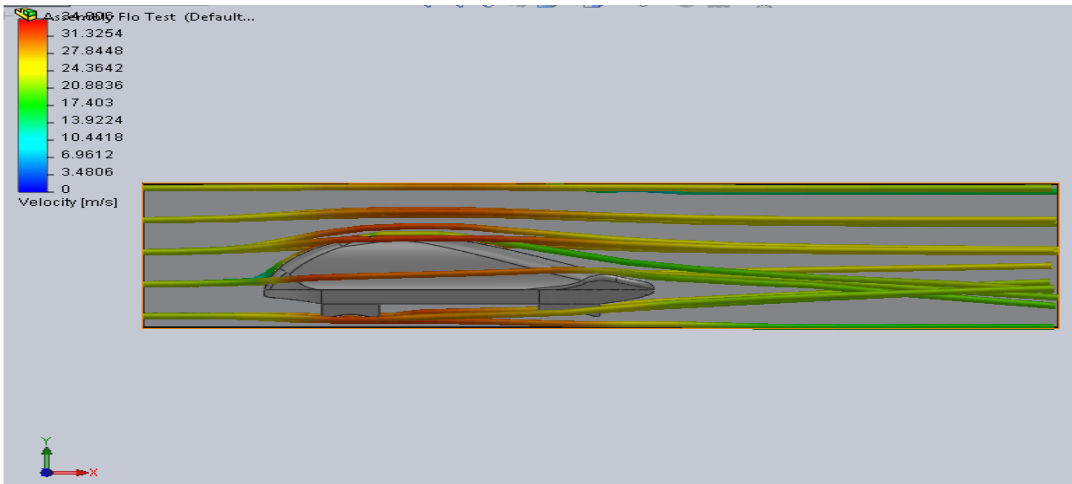

Figure 4.1: Flow of air analysis/streamline

- Fluid of flow: air
- Inlet: volume flow rate

Example, car move a maximum speed 80km/h (Assumption)

= 80km/h

= 80 000 m ÷ 3 600 s

V = 22.22 m/s

V̇ = volume × velocity

= (2m × 1.8m) × 22.22m/s

= 80 m^3/s (volume flow rate of air)

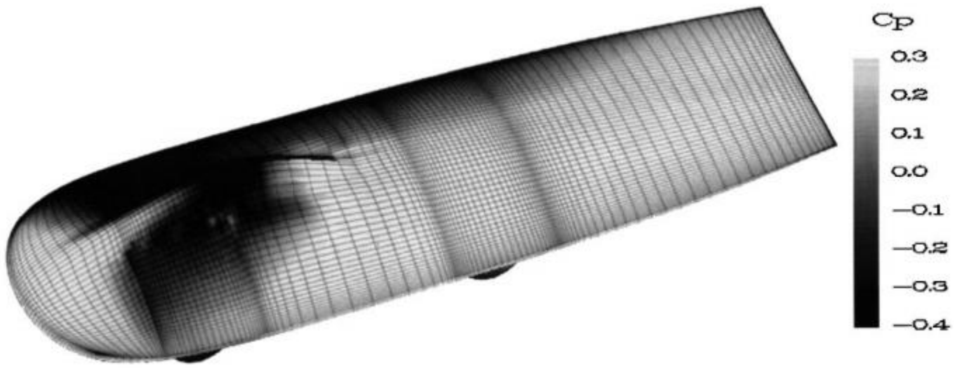

Figure 4.2: Pressure distribution of the surface

4.2.2 Moments and Forces on the Bottom Part

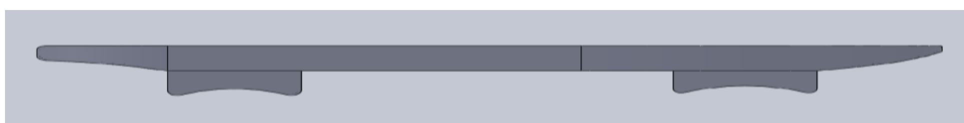

Figure 4.3: Side View Bottom Part

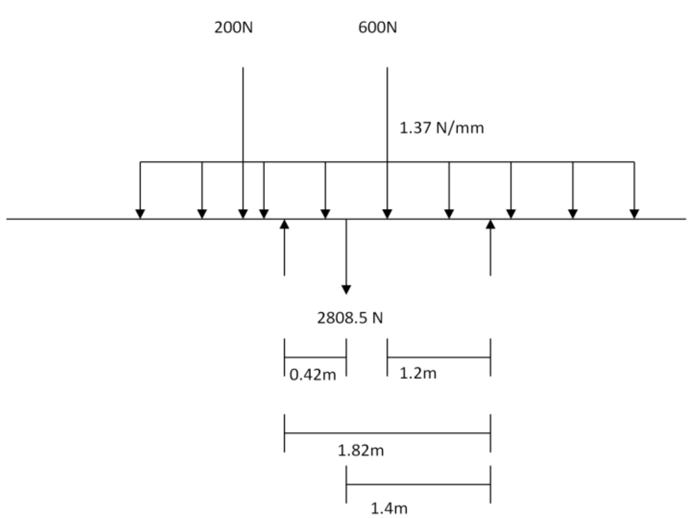

Figure 4.4: Distance of bottom part

To Find the Uniform load from chassis

Long chassis = 2050 mm

Weight chassis+ batteries (20 kg each box) + panel + motor + body shell = 2800 Newton (Assumption)

Uniform load $= \frac{2800}{2050} = 1.37N/mm$

And the static load: =1.37N/mm × 2050mm

=2808.5 ***Newton***

Find Front =

$\sum Ma = 0$

$M\,A = 200(2.25) - Front\,(1.82) + 2808.5(1.4) + 600(1.2)$

0 = 450 – 1.82Front + 3932 + 720

1.82 Front = 450 + 3932 + 720

Front = 5102 ÷ 1.82

Front = 2803.3 ***Newton***

Find Rear =

$\sum Mb = 0$

$M\,A = 200(0.25) - 2808.5(0.42) + 600(0.65) + Rear\,(1.82)$

0 = 50 – 1180 + 390 + 1.82Rear

1.82 Rear = 740

Rear = 740 ÷ 1.82

Rear = 406.6 ***Newton***

4.2.3 Mathematical Simulation

Consider the main forces acting on the car, see sketch below.

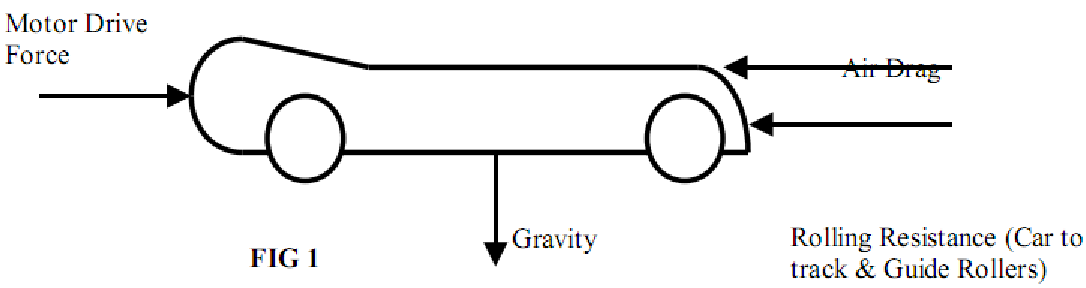

FIG 1

Figure 4.5: Gravity force

i. Gravity

Gravity acts vertically down, the gravity force in Newton is determined by multiplying the Mass (M) of the object in kilograms by the gravity constant 9.81 m/s/s. However when the car is on a slope a component of the gravity force will be acting down the slope. The magnitude of the gravity force component acting down the slope depends on the angle of the slope. When the car is travelling down the slope this force will tend to speed it up, conversely if the car is going up the slope this force will tend to slow it down and may even stop the car if the car does not have sufficient speed or drive force to overcome this gravity component.

ii. Air Drag

Air drag is due the passage of air over the car, it can be due to the car moving through the air or air passing over the car such as a prevailing wind. This force acts parallel to the air flow and in the same direction as the air flow

For a complete explanation of air drag refer to standard fluid dynamics tests, but simply put:

Air Drag = ½ × Air density × Drag Coefficient × Frontal Area × Velocity

4.3 CONCLUSION

This chapter discuss about all the result in this research. Also discuss about what happened in the analysis result and to determine which the best result for this research. And than discuss of the mathematical simulation of the bottom part for find the value of Newton.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.0 INTRODUCTION

This chapter include summaries the result and provides conclusion of the present work. Recommendations for further work are also presented in this chapter.

5.1 CONCLUSION

From the outcomes at the end of this design and analysis planning, there are a few highlights that can be considered as meeting the objectives and gaining values. The initial idea was to find out if there is an alternative in producing a Formula Varsity race car body. As total design method is carried out throughout the whole design and planning process, it is believed that this proposed alternative can lead to a better product in a few different perspectives and this is supported by the figures and conceptual analyses included in the design and planning process.

It is proven that the final product had added value to the race car. as discussed in the detail design section, the Formula One analogous design had given the car better aerodynamic properties and stability. Besides, the use of high strength fiberglass reinforced improves the race car safety factor. This is a plus point as safety is in important criterion in motor racing. Also, substantial weight reduction is achieved when the car body is fabricated using fiberglass and carbon fiber as this material is low in density.

5.3 RECOMMENDATIONS

The project planning should be start and done before the project start, do all the process on time according to the Gantt chart, so that all the process can be completed. The skills and knowledge in the solar car is an essential element for analyzing the parts of the solar car. For addition, the project should be improve by using the materials that more light and have better properties, so they can give the best performance, the great features and more ergonomic value and to the project.

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APPENDIX A

Missouri-Rolla Solar Car, 2003 American Challenge Champion

Small Cross-Sectional Area

Slightly Curved Underbelly

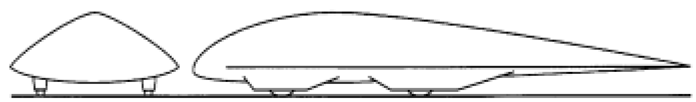
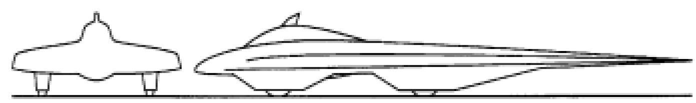
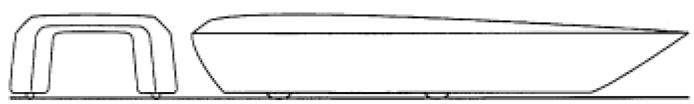
Principia Solar Car: Thin and Low to Ground

d


Kansas State Car: Streamline and Gentle Sloping Curves

Kansas State Solar Car: Use of fairing on all four wheels

APPENDIX B

	Basic shapes	$C_D \times A$
A	The four–wheel, modified '93 Dream $A = 1.064\ m^2$ 	0.126
B	The laminar flow airfoil image type 1 $A = 0.952\ m^2$ 	0.108
C	The laminar flow airfoil image type 2 $A = 0.947\ m^2$ 	0.119
D	The type focusing on generated output $A = 1.095\ m^2$ 	0.185

APPENDIX C

Flow Analysis

Center Cross-Section including Canopy

Analysis calculated at an air speed of 40mph

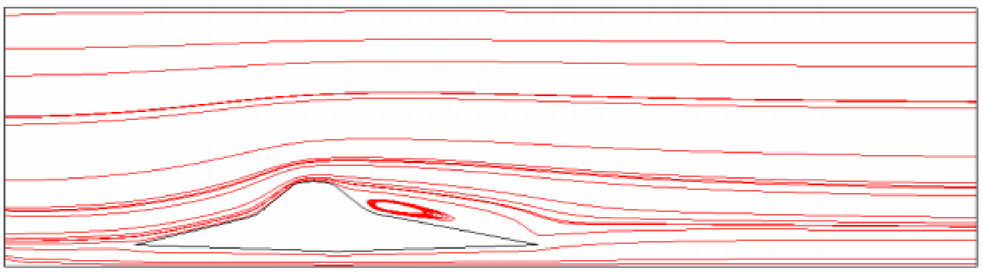
Constants:

Air Density : ρ 1.29 kg/m^3

Air Velocity V ~ = 20 m/s

Dynamic Viscosity: $\upsilon = 1.5 \times 10^{-5}$ N*s/m^2

Streamlines: Air flowing from left to right



Pocket of Turbulent flow apparent behind cockpit

Velocity