EML 4905 Senior Design Project

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SHELL ECO-MARATHON
25 % of Final Report

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This B.S. thesis is written in partial fulfillment of the requirements in EML 4905. The contents represent the opinion of the authors and not the Department of Mechanical and Materials Engineering.

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Marco Betancourt, Bryand Acosta, and Fernando Pinheiro and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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Team Leader	Team Member	Team Member

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Abstract

The main objective of this project is to design a fuel-efficient car prototype moved by an internal combustion engine to participate in the 2013 Shell Eco Marathon in Houston, Texas during the dates of March 29th- April 1st. “Panther Killer” used Panther Rage G2 and Panther Rage cars as reference but a new car was build from scratch envisioning an efficient transition to the internal combustion category of the competition. Abiding by the extensive rules and regulations of the competition, our group modeled, manufactured and tested a vehicle with optimum aerodynamics, minimum weight and reasonable budget that fit the realistic guidelines of the project.

1 Introduction

1.1 Problem Statement

One of the main concerns of our generation is the gradual increase of the earth's temperature, in other words, the phenomenon called Global Warming. This constant elevation of the earth's thermometers could lead to catastrophic results in a matter of decades, such as the melting of the poles, disappearing of islands and extinction of races. The biggest catalyst to this phenomenon is the emission of greenhouse gases. Greenhouse gases, such as carbon dioxide and methane, are mainly generated due to the combustion of fossil fuels, one of them being oil that moves our cars. The accumulation of those gases in the layers of the atmosphere is called the greenhouse effect.

Keeping in mind the threats our environment is currently under, Shell created a few decades ago the Shell Eco-Marathon competition, challenging students to not only look for other alternatives of energy but also, to improve and optimize the ones that can be found today. Even though our government invests over $51 billion dollars per year in renewable energies[i], over 80% of the energy we use in the world today, still comes from fossil fuels against 9% from renewable sources. Therefore, keeping in mind oil will still be the main source of energy for our cars in the near future; the Shell Eco-Marathon has helped students to explore ways to improve mileage per gallon in such vehicles. [ii]

1.2 Motivation

The project was first introduced to the group by one of the team's members, Bryand Acosta. Bryand, who had contacted members that were part of Panther Rage G2 team in the previous year, saw a great opportunity in this project to keep the tradition at Florida International University (FIU) of participating and representing the school in this internationally recognized competition. Last year's team had nothing but great feedback to give to "Panther Killer", and after surpassing their own expectations in the competition, they highly recommended the experience for the present team.

Made up of members that had previously few or no "hands on" experience with the concepts learned throughout our engineering courses at FIU, our team was immediately attracted by the chance of building a car prototype. This project involves basic concepts of real sized cars such as design of a chassis, a body, steering and braking systems and most importantly putting it all to work with an engine. Combining these elements with the challenges of reducing weight, increasing aerodynamics and respecting the rules of the competition, this year's team saw in the Eco Shell Marathon the perfect components to fulfill the requirements of Senior Design Project.

Panther Killer has utilized concepts learned not only in the classroom but also in computer programs, such as Solid Works and CAD, which were essential in order to make some of the simulations of the car.

Last, the team that is representing FIU this time around, is looking forward to travel to a different state and network with students from different countries and exchanging ideas and different concepts that are utilized in the engineering world. The team sees the competition as a rewarding experience for all the months of hard work put into it.

1.3 Literature Survey

This survey has the purpose of letting the team members become informed on the theory behind the basic functionality and operation of the different components and systems that come together to make an automobile. Furthermore this survey will extend into assessing the technologies used by the top ranking competitors in the Shell Eco-Marathon over the years.

Regulation Requirements

Identification Requirements

a) Logos, official partner streamers and racing numbers must be fixed to the vehicle body in accordance with the diagram provided (see Chapter II) such that they can be clearly read during any public presentation, in promotional films and on all photographs for team use, school use, press or promotional material.

b) Under no circumstances may the Shell logos, the partner streamers or racing numbers be modified, either on the vehicle or on any other documentation. It is prohibited to cut the stickers supplied by the Organizers. Their dimensions are as follow:

For each side and for the front of the vehicle: a Shell logo, 20 x 20 cm.

For each side and for the front of the vehicle: racing numbers, 20 x 26 cm

For each side, on the lower part of the body: a partner streamer, 90 x 6cm.

c) A mandatory 10 cm space must be left free on all four sides of the Shell logo.

d) Any other sponsor names / logos must be smaller than the Shell logo. The sponsor stickers must fit within a surface of 400 cm2 (empty space included)

e) In the event of a breach of this rule, the Organisers reserve the right to remove any sponsor logos.

f) Furthermore, the trademarks or logos of other energy companies, direct competitors of event partners, tobacco companies and alcoholic drinks producers are prohibited.

g) All vehicles are subject to the Organisers' approval concerning these provisions.

Driver Weight

a) Drivers of Prototype vehicles must weigh at least 50 kg in full driving gear, including communication devices, prior to an attempt. Ballast must be fitted to the vehicle in the event the minimum weight requirement is not met. This ballast must be provided by the Team, and must be effectively tied down and secured to the vehicle to ensure no danger for the Driver in the event of collision or roll-over. It must be easily detachable for weighing.

b) The Driver (in full driving gear, including communication devices) and the ballast may be weighed before or after each official attempt. A weight loss of up to 1 kg during an attempt will be tolerated.

Driver Safety

a) For practice and competition, Drivers must wear Motorcycle or Motorsport style helmets that comply with the safety standards specified in Chapter II of the Official Rules of each Shell Eco-marathon event (bicycle/riding/skating type helmets are not permitted). The helmet labels must be clearly readable. Helmets worn by both the Driver and Reserve Driver will be subject to inspection.

b) Only full-face or three quarter helmets are permitted. Generally, the full-face and three quarter style helmets can be affixed with face shields which are highly recommended. If a face shield is not utilised, safety goggles are required. The helmets must correctly fit the Drivers; otherwise they will not be approved for the event.

c) All Drivers must wear a racing suit as the outermost layer of clothing (fire retardant highly recommended). Casual clothing and street wear are not permitted. Chapter II provides further guidelines regarding the racing suit specifications and availability. Wearing synthetic outer clothes or underwear is strictly forbidden for Drivers when seated in their vehicle.

d) Gloves and shoes are required and must be provided by the team; bare feet or socks only are prohibited.

e) The Driver's seat must be fitted with an effective safety harness having at least five mounting points to maintain the Driver in his/her seat.

f) Each vehicle must be fitted with a fire extinguisher (ABC or BC type). All Drivers must be trained in the use of said fire extinguisher. This extinguisher must have a minimum extinguishing capacity of 1 kg (2 lb for US application); equivalent size extinguishers are not permitted. It must be full and have a certificate of validity bearing the manufacturer's number and the date of manufacture or expiry.

g) An emergency shutdown system, operable from both, the exterior of the vehicle and the interior driver position, must be permanently installed on all vehicles (not part of the detachable bodywork used to allow driver access).

Vehicle Design

a) Prototype vehicles must have three or four running wheels, which under normal running conditions must be all in continuous contact with the road.

b) Vehicle bodies must not be prone to changing shape due to wind and must not include any external appendages that might be dangerous to other Team members; e.g. pointed part of the vehicle body. Any sharp points must have a radius of 5 cm or greater, alternatively they should be made of foam or similar deformable material.

c) Windows must not be made of any material which may shatter into sharp shards. Recommended material: Polycarbonate (e.g. Lexan)

d) The vehicle chassis must be equipped with an effective roll bar that extends 5 cm around the driver’s helmet when seated in normal driving position with the safety belts fastened. Any roll bar must be capable of withstanding a static load of 700 N (~ 70 kg) applied in a vertical, horizontal or perpendicular direction, without deforming (i.e. in any direction).

Visibility

a) The Driver must have access to a direct arc of visibility ahead and to 90° on each side of the longitudinal axis of the vehicle. This field of vision must be achieved without aid of any optical (or electronic) devices such as mirrors, prisms, periscopes, etc. Movement of the Driver's head within the confines of the vehicle body to achieve a complete arc of vision is allowed.

b) The vehicle must be equipped with a rear-view mirror on each side of the vehicle, each with a minimum surface area of 25 cm2 (e.g. 5 cm x 5 cm). The visibility provided by these mirrors, and their proper attachment, will be subject to inspection. An electronic device must not replace a rear-view mirror.

Clutch, Transmission and Exhaustion

a) All vehicles with internal combustion engines must be equipped with a clutch system.

b) For centrifugal / automatic clutches the starter motor speed must always be below the engagement speed of the clutch.

c) The installation of effective transmission chain or belt guard(s) is mandatory.

d) The exhaust gases must be evacuated outside the vehicle body.

e) All exhaust components must be made of metal.

Dimensions

a) The maximum height must be less than 100 cm.

b) The maximum height measured at the top of the Driver's compartment must be less than 1.25 times the maximum track width between the two outermost wheels.

c) The track width must be at least 50 cm, measured between the midpoints where the tyres touch the ground.

d) The wheelbase must be at least 100 cm.

e) The maximum total vehicle width must not exceed 130 cm.

f) The maximum total length must not exceed 350 cm.

g) The maximum vehicle weight, without the Driver is 140 kg.

Wheels, Braking and Steering

a) All types of tires and wheels are allowed.

b) Front wheel or rear wheels steering is permitted. If rear wheel steering is used then it should be easy for the driver to locate the straight-ahead position.

c) The turning radius must be sufficient to enable safe overtaking as well as negotiating the turns of the track.

d) Vehicles must be equipped with two independently activated brakes or braking systems; each system comprising of a single command control (lever(s) working together or foot pedal), command transmission (cables or hoses) and activators (callipers or shoes).

e) One system has to act on all front wheel(s), the other on all rear wheel(s). When braking on two steering wheels at the front, two activators (callipers or shoes) have to be used-one on each wheel, commanded by only one command control. In addition, the right and left brakes must be properly balanced.

f) The effectiveness of the breaking systems will be tested during vehicle inspection. The vehicle will be placed on an incline with a 20 percent slope. The brakes will be activated each in turn. Each system alone must keep the vehicle immobile.

Competitor Assessment

To assess the competition, the team gathered the results of the Shell Eco-Marathon, Houston 2012, in the gasoline combustion fueled engine category, and took a further look into winning teams from Europe and East Asia. Unfortunately some teams do not publish their research on the Internet and because of this fact it was not possible to research some of the most important competitors

Evolution Supermileage team

EVO 4 vehicle

Figure 1 - Evo Supermileage

Results:

673km/L

Body:

Monocoque carbon fiber, with 3 wheels

Engine:

modified briggs &Stratton engine with custom overhead cams and valves, 47cc of displacement, 13.7:1 compression ratio, sequential electronic fuel injection with programmable ECU and electric starter.

Transmission:

Centrifugal clutch, single gear ratio 10:1, with replaceable gears to vary from 9:1 to 13:1

Vehicle Weight:

47kg

Cost:

50000$ Canadian dollars and 8000 hours of fabrication

Alerion Supermileage

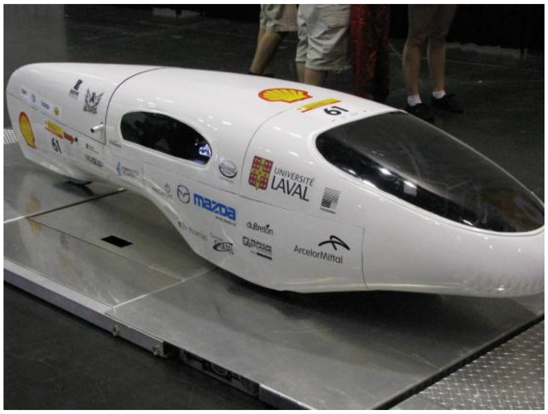

Figure 2 - Alerion Supermileage

Results:

1347km/L

Body:

Monocoque carbon fiber, with 3 wheels

Vehicle Weight:

94lb

Project Infinity

Figure 3 - Project Infinity

Results:

1347km/L

Body:

Monocoque carbon fiber, with 3 wheels

Wheels:

Michelin 44-406

University of Science of Malaysia

Figure 4 - Univ of Malaysia

Body:

Aluminum frame on composite honeycomb sandwich for the floor pan

Wheels:

Custom made hubs for ceramic angular contact bearings, as replacement for OEM wheel hub

Results:

Could not finish race because the car could not travel up a steep slope for lack of a lower gear ratio

Eco Illini

Figure 5 - Eco Illini

Body:

Monocoque carbon fiber, with 3 wheels

Engine:

Saito 57cc 2 cylinder boxer engine for hobby aircraft, with custom throttle body for electronic fuel injection, with Megasquirt 3 ECU, and electric start

Transmission:

Single reduction transmission with a 451c wheel size sprocket

Team Green

Figure 6 - Team Green

Results:

6603 mpg

Body:

Monocoque carbon fiber, with 3 wheels

Engine:

34cc single cylinder engine customized with 2 sparkplugs, variable inlet valve timing and fuel injection with an engine management system provided by General Engine Management Systems Ltd

Transmission:

Centrifugal Clutch

Wheels:

20in modified BMX style bicycle wheels with Michelin low rolling resistance tires, and custom hubs.

Weight:

42kg

Ecolancers

Figure 7 - Ecolancers

Results:

318 mpg

Body:

Aluminum structure with sheet metal body and 3 wheels

Engine:

GXH Honda 49cc single cylinder engine with fuel delivery via carburetor

Transmission:

Extreme Duty Centrifugal Clutch coupled with a single gear 12:1 reduction as large as the wheel itself

Wheels:

Bicycle wheels with Michelin low rolling resistance tires.

Weight:

42kg

Background Theory

Engine Efficiency

Competition guidelines state that every internal combustion engine used to compete must use a four-stroke cycle to produce power.

In theory the internal combustion engine efficiency is limited to that of the Carnot-cycle

The efficiency for a Thermodynamically reversible Carnot cycle engine is given by the equation:

$$\eta = 1 - \frac{T_C}{T_H}$$

where: η is the efficiency

T_C is the absolute temperature in the cold heat reservoir

T_H is the absolute temperature in the hot heat reservoir

The Carnot Cycle theorem states that:

"An engine operating between two heat reservoirs can not be more efficient than a Carnot engine operating between these same reservoirs."[iii]

The temperature of the cold reservoir is given by the ambient temperature outside the engine, which should be between 15°C and 25°C during the month of April in Houston, Texas.[iv] On the other hand the maximum temperature that could be achieved would be limited by the metallurgic properties of the engine and this temperature is also referred to as the adiabatic flame temperature, which is itself a function of the products of combustion used. The adiabatic flame temperature is both difficult to quantify in practice and theoretically due to hysteresis in temperature sensors and due to the fact that incomplete combustion will change the molar ratio of products of combustion being produced.

Furthermore the engine of choice for this competition has to be a four stroke, which makes it an Otto cycle engine for which the efficiency equation is given by

$$\eta_{TH} = 1 - \frac{1}{r^{(\gamma-1)}}$$

where: r is the compression ratio

γ is the specific heat ratio

The compression ratio is specific to the engine design and higher values increase the engine efficiency, yet it is limited by the fact that higher ratios may cause the combustion in the cylinder to occur prematurely, this is a phenomenon called engine knock and it will adversely affect engine efficiency and life expectancy. Engine efficiency is in most part a function of this value since for air/fuel mixtures γ is usually taken to be 1.4, but it is important to note that this value rises with increasing temperature.[v] This equation gives the thermal efficiency of the engine, which is the heat energy it can actually extract from the products of combustion to transform into mechanical work.

Non the less the efficiencies that can be derived from the above equations far exceed the real world efficiency measured from a real world engine which initially has an inefficient combustion, and then has to overcome friction, aerodynamic drag of gases inside the engine, parasitic losses from accessories, alternators and pumps, poor valve timing causing vacuums during the intake stroke or pressure loss during compression and expansion, all this while loosing heat through the cylinder walls. This real world efficiency is termed the brake specific fuel consumption and is the ratio between the fuel consumed and power produced, and it is measured in $\frac{grams}{kW \times h}$

$$BSFC = \frac{r}{T\omega}$$

Where: r is the rate of fuel consumed in g/s

T is the torque produced by the engine in Newton•Meters

ω is the engine speed in radians/second

Note that by knowing the energy density of the fuel in terms of its mass it is possible to calculate how much energy is actually stored in that fuel in order to get a number in terms of strict energy efficiency.

Vehicle Efficiency

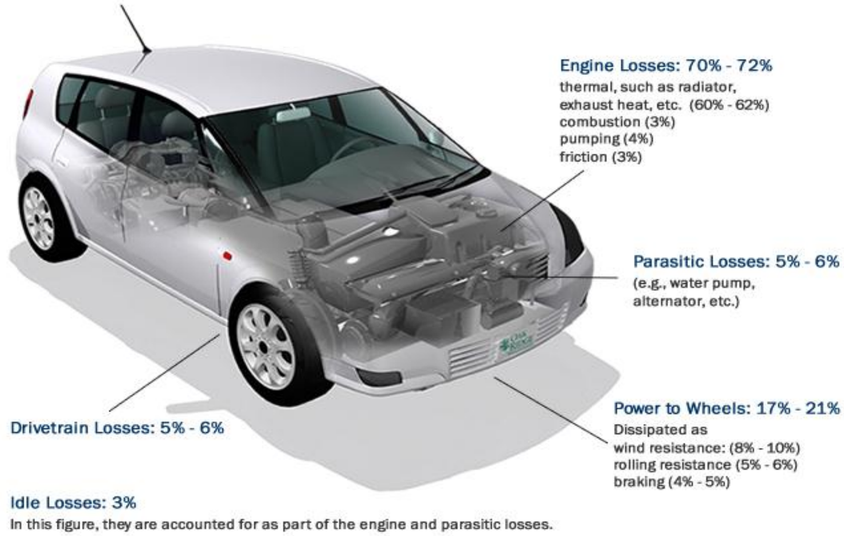

Figure 8 – Distribution of energy in a vehicle

The energy that the engine can convert to mechanical work is limited by its thermal efficiency and the mechanical losses inside the engine, but not all the energy produced by the engine is available to energize the transmission, there are also parasitic losses that arise from using energy from the engine to pump fluids throughout the vehicle and create electricity in order to power the car's electrical system.

The powertrain efficiency is given by the product of the efficiencies of all mechanical components starting at the engine and ending at the wheels axle. For our design this includes the engine's thermodynamic efficiency, its mechanical efficiency, and that of the transmission plus the parasitic losses. It can also be calculated as the ratio between the powertrain output, and the power associated with the fuel consumption rate.

$$\eta_{PT} = \eta_{TH}\eta_{M}\eta_{T} = \frac{P}{P_{Fuel}}$$

After all this losses the power that is available at the wheels also has to overcome aerodynamic drag, rolling resistance forces, and the weight of the vehicle unless the surface is perfectly flat, together this make up the forces required for the vehicle to maintain a given speed, any power available at the wheels, in excess of this will be available for acceleration

Improving Vehicle Efficiency

(to be completed)

2. Design Alternatives

2.1 Overview of conceptual design

Weight:

The target weight of our vehicle is less than 150 lbs

Body:

The body and frame should combine to make a sturdy and structurally safe aerodynamic shell. Its construction must consist of a mixture of lightweight materials: aluminum, carbon, and glass-reinforced plastics with honeycomb cores are being considered; nonetheless a monocoque build is unlikely due to temporal constraints.

Engine:

Must be a small and fuel efficient engine under 50cc

Fuel Delivery System:

Electronic fuel injection is preferred over carburetion to achieve stoichiometric combustion, since Maximum flame temperature occurs at the 14.7:1 air/fuel mixture combustion ratio[vi]

Transmission:

Must allow for the engine to be started under unloaded conditions even if the vehicle is in movement, and should at least provide one reduction gear to have the engine operating in the most efficient range of its power band while making the vehicle drivable in the speed range of 0-20 MPH

Starter

The starter must allow for a single person inside the cabin to turn the engine on without taking their hands of the steering wheel.

Wheels and tires:

Michelin designs and manufactures ultra low rolling resistance tires specifically for this competition, these are meant to fit over standard bicycle wheels, outfitting such wheel with ultra low friction bearings and making this whole assembly as light as possible would be ideal for the design.

2.2 Proposed Design Alternatives

Wheels:

Michelin ultra low rolling resistance 44-406 tires which are 16in inner diameter, and 20in overall diameter using custom made hubs for ceramic ball bearings[vii].

Tires:

Shell has a partnership with Michelin and offers those for purchase at $78 per tire. Michelin ultra low rolling resistance 44-406 tires, which are the ones offered to the teams registered for the competition are available on a first come, first serve basis. Some important characteristics of this tire are:

- Rolling resistance: 2 kg/t (kilogram/ton)
- Suitable pressure: 50PSI
- Weight: About 150 grams
- Suitable crochet-type rim reference: 20''x1.75''
- Section Width: 45 mm
- Overall diameter: 500 mm

Hubs:

Custom made hubs for ceramic ball bearings[viii]

Engine:

In order to select the engine we must first examine the power requirements of our vehicle. For the preliminary analysis there will be several assumptions made, and these will be clearly stated.

The power requirements of out vehicle for any given speed are given by the product of the sum of the forces acting against our vehicles motion and the vehicle's velocity:

$$P = FV$$

$$P = (mgC_{RR} + \frac{1}{2}\rho C_D A V^2)V$$

Where:

P is the power required in Watts

M is the mass of the vehicle
g is the acceleration due to gravity
C_{RR} is the coefficient of rolling resistance
ρ is the density of the atmospheric fluid, 1.293 kg/m^3 for air
C_D is the vehicles coefficient of drag
A is the frontal area of the vehicle
V is the vehicle's velocity

The total energy in watts consumed by the vehicle is given by the product of the power necessary to overcome the forces multiplied by the time the vehicle will be in operation plus the energy necessary to bring the vehicle up to that speed

$$E = \frac{1}{2} m V^2 + Pt$$

The torque at the crankshaft T, multiplied by the angular velocity gives the power supplied by the engine at any given engine speed:

$$P = T \times \frac{RPM \times 2\pi}{33000}$$

This is a function that cannot be modeled unless actual data about the engine's torque output has been recorded on a dynamometer as a torque curve.

Using the above equation for the power required, at the wheel, to overcome external frictional losses, and after accounting for the vehicle's internal mechanical losses is shown below, using the following parameters:

Table 1 - Engine selection parameters

m (kg)	136.3636364
g (m/s^2)	9.8
C_{RR}	0.0025
ρ (kg/m^3)	1.225
C_D	0.15
A (m^2)	0.42
R (m)	0.254

Table 2 - Engine selection

Engine model	Size	CR	Power Output	Torque	Fuel Consumption	Price
GY6-QMB long	49cc	10.5:1	2.82HP (2.1kW) @6500Rpm	2.3lb-ft (3.1N.m) @5500rpm	9.65oz/HP.h (367g/Kw.h) 1.04 L/hr @ 6500 rpm	$359.99

Honda GX25	25cc	8.0:1	1HP (0.72kW) @7000rpm	0.74lb-ft (1.0Nm) @5000rpm	0.54 L/hr - 7000 rpm	$225.00
Honda GX35	35.8cc	8.0:1	1.3HP (1.0kW) @7000rpm	1.3lb-ft (1.6Nm) @7000rpm	0.71 L/hr - 7000 rpm	$245.00
Honda GXH50	49.4cc	8.0:1	2.1HP(1.6kW) @7000rpm	2.0lb-ft(2.7Nm) @5000rpm	0.91 L/hr - 7000 rpm	$325.00

The engines under consideration are all four-stroke engines below 50cc, and there are two main families of engines being considered:

The GY6 style engines are popular in the small scooter, ATV and Go-kart markets. There are various performance upgrade parts and documented modifications for this type of engines available, including fuel injection conversions. This engine has a higher compression ratio, which is something desired for higher thermodynamic efficiency. The power rating and maximum torque are also the highest in the list with almost a 33% advantage over the comparable Honda GXH50, and at 500rpm less than. On the downside; its fuel consumption is about 10% higher at this rated engine speed. This engine is sold ready for a drum brake setup, and comes equipped with an electric starter, and a continuously variable transmission (CVT) that will produce gear ratios from 0.8 to 2.4.

The Honda engines are made in different sizes from 25cc to 50cc, and include a recoil starter, and a centrifugal clutch. For our purposes this starter would have to be changed to an electric type in order to make it possible for the driver to turn the engine on and off from the cockpit while the vehicle is in motion. On the other hand the centrifugal clutch might come in useful for the development of a discrete reduction gearing system with automatic engagement. Nonetheless the amount of support material and documented modifications for this type of engines is also scarce.

Taking this factors into account and the expected power requirements of our vehicle, the team has decided to opt for the GY6 engine.

Figure 9 - Engine Top View

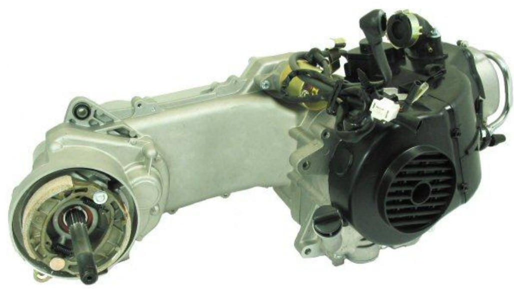

Figure 10 - Engine side view

- Output Shaft Length: 122mm
- Accommodates 12-13 inch wheel size
- Set up for drum brake

Fuel Delivery System:

The engines above comes carbureted and the team is considering to have a fuel injected design that would be satisfied by implementing small engine fuel injection and ECU kits designed by Ecotrons, Microsquirt, or MBE Motorsports.

Fuel:

86-octane regular gasoline

Clutch and Transmission:

The GY6 engine comes with a proprietary centrifugal clutch and a continuously variable transmission, or CVT. This transmission consists of a pulley on the engine shaft, and another on the output shaft with a belt transmitting power between them. The way different gear ratios are achieved is by having the pulleys be made of independent conical halves (sheaves) that can move relative to each other increasing or decreasing the gap between them so that the belt sits at different pitch circles, the ratio between the two pitch circles would give us the gear ratio for that specific configuration, to obtain higher understanding of the device is an exploded view in the diagram below:

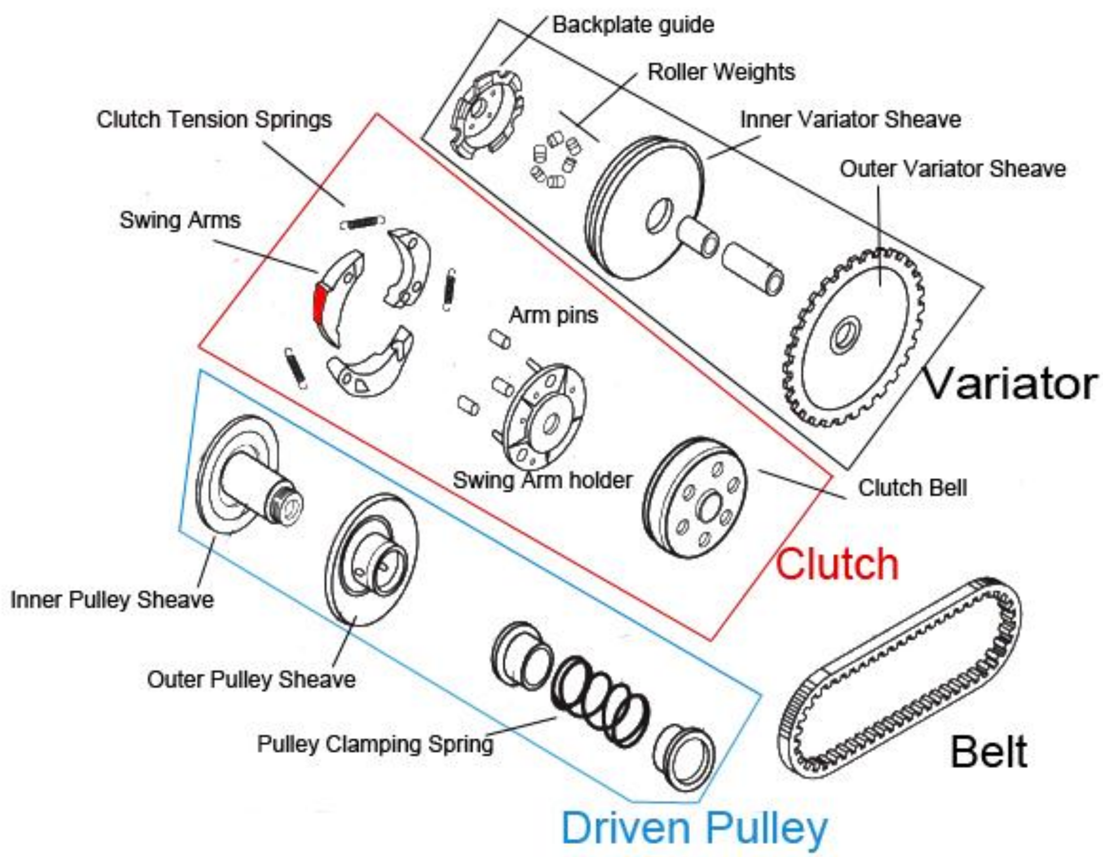

Figure 11 - Parts breakdown

The process to arrive to those two pitch circles is governed by centrifugal, spring, and frictional forces. Power from the engine is originally transmitted to the variator's geared outer sheave via a 62:14 gear reduction, as the assembly rotates the massed rollers start pushing outward, and against ramp-like guides in the variator's back-plate, pushing these two apart and reducing the gap between the two halves of the variator. As this happens the belt is driven outward in the variator while being driven inward in the output pulley, a motion that is opposed by the clamping spring.

Changing the weight of the rollers, and the stiffness of the clamping spring can control the rate at which the changes occur. This is unfortunately something that we cannot model mathematically unless we know several dimensions, and material properties about the transmission that are currently not available. Most of the data that will help us optimize this transmission will come from obtaining direct measurements through experimentation and what is referred to as tuning in the racing world.

The centrifugal clutch consists of two main parts; the clutch swing arm assembly, which rotates with the driven pulley, as the angular speed increases the arms swing outward due to the centrifugal force and ultimately engage with the clutch bell. The clutch bell being linked to the CVTs output shaft delivers the power to the wheel. This clutch is extremely important and needs to be tuned to achieve the following goals:

1. The clutch must be disengaged when the engine is idling, to comply with the competitions guidelines
2. The clutch must engage quickly as the engine is throttled and must disengage instantly when the engine is turned off. These two things are extremely important for transmission efficiency and to enable the vehicle to coast freely without being subjected to braking forces due to compression in the engine piston when the engine is off.

To achieve this goal we will need to use different clutch springs in order to find the appropriate ones to satisfy the team’s goals.

Unfortunately while a CVT offers very simple operation with virtually no driver interaction, it is important to note that research into these transmissions indicate that these can be very inefficient, with values as low as 75%, mainly due to belt slippage, other sources that contribute to this inefficiencies are friction at surface contacts of bushings and bearings, which the team will attempt to reduce once the engine is physically dissected, and the parts measured, in order to assess if suitable replacements can be found

Starter:

Some of the engines considered come with electric starter while others need a ripcord to be pulled in order to start them. The engine for this design must be electric so the driver and/or ECU can control when the engine turns on and off, allowing the car to cruise with the engine off and then be started from within the cockpit when the speed falls below a predetermined level

Body:

Being that the Shell Eco Marathon is a competition about highest miles per gallon (mpg), the team will try to design the entirety of the car while trying to minimize the energy loses. One way that the team will do so, is by designing an exterior body for the car with the best aerodynamics possible. This is achieved by designing a shape in which the drag is reduced as much as possible. Figure 13 below shows how the shape of an object affects how much skin friction drag is felt as opposed to pressure drag.

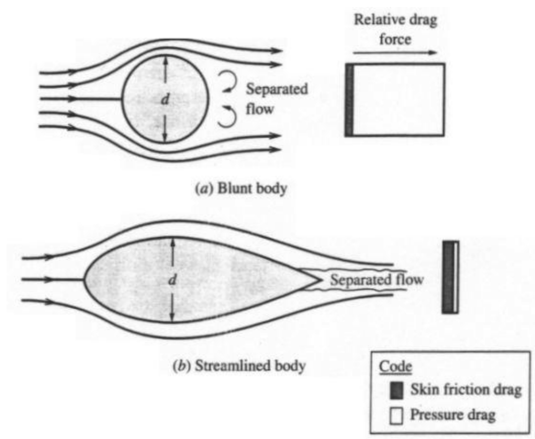

Figure 12 – Body efficiency

With this goal in mind, a preliminary body has been designed in which the raindrop shape is emulated as much as possible, and can be seen in figure 14. This current design was made with the intention of not only having a raindrop shape in the x-y plane cross-area, but also when taking the cross area from an angle of said plane. That is, if the wind is coming directly from the front or from angle, it will encounter a 2D cross-area that resembles a raindrop. This was an important factor when designing the car as winds will not be directly in line with the velocity of the car as the racetrack is a circular one.

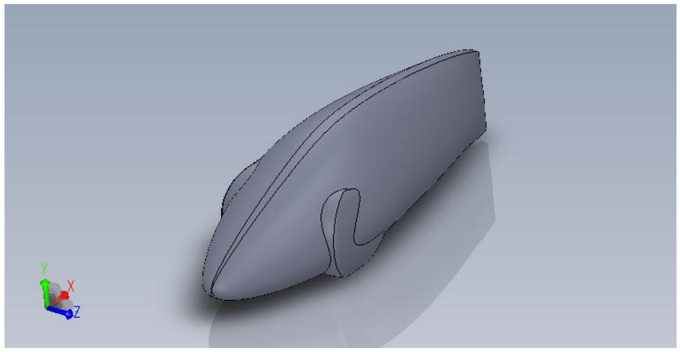

Figure 13 – Body solid works

Frame:

When designing the frame of the car many things need to be considered: dimensions, total weight, weight distribution, strength, etc.

When considering the dimensions of the frame, the goal is to design it so that it is as slim as possible within regulation. It was also intended to have the ratio of length to width be relatively high as that would allow for the body to be as compact as possible while staying consistent with the intended aerodynamics.

For the design, the team also had to consider the location of all the components that make it a function car. Figure Y shows the Dalhousie University Supermilage team car frame. This picture accurately shows how the team plans on placing the components of the car: two wheels in the front, one in the back, steering system in the two front wheels, engine directly behind the driver's backrest. A few more tubes will be added in order to increase the driver's safety and comply with the competition's safety regulations.

Figure 14 – Frame sample

Steering system:

While researching and designing the steering system, the team took into consideration the radius of turning and how it would impact the size and design of the frame and body of the car. Figure 16 shows the Ackermann Steering geometry. As can be seen in the figure, the larger the distance between the front and back wheels of the car, the larger the radius of turning is. This goes against the team's goal as they strive for the lowest turning radius for highest efficiency. Also, having a lower turning radius means the wheels need to turn more in order to compensate, and this in turn forces the car design to be wider in order to allow for the extra space needed for the wheels to turn.

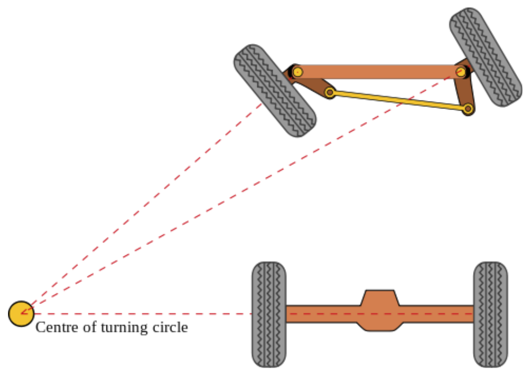

Figure 15 – Steering system

3 Project Management

3.1 Overview

As a team working together for the best outcome in the competition, the team envisions to put in the same amount of work in the project. All members are fully aware of all meetings, expectations, objectives and tasks that must be met in order to make this journey a successful one and have all committed in putting equal time and effort into doing so.

3.2 Breakdown of Work into Specific Tasks

Naturally building a car prototype will involve putting several pieces of a puzzle together successfully in order for the final product to function ideally. The prototype can be divided in several different small sections such as Engine Selection, Body Design, Material Selection, Chassis (Frame), Steering System, Braking system, Wheel and Rim selection. Since the project design involves participation in a competition, it is also very important to assign members tasks that will assure the team is complying with the regulations and deadlines imposed by the organizers.

3.3 Project Timeline

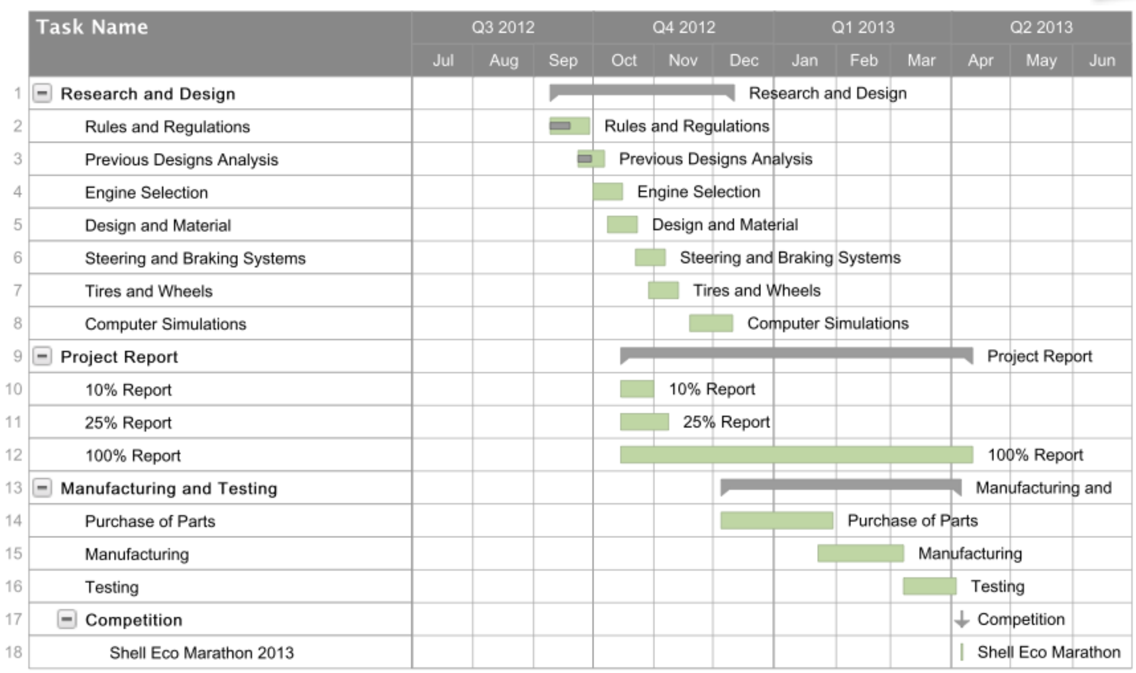

Figure 16 - Project Timeline

3.4 Breakdown of Responsibilities

For the 2013 Eco Shell Marathon team, the tasks have been distributed as follows:

- Marco Betancourt: Engine research and selection, Fuel selection and delivery system and Transmission system.
- Bryand Acosta: Aerodynamic research, body design, material selection and frame design.
- Fernando Pinheiro: Steering system, braking system, wheel and rim selection. Responsible for rules, regulations and competition deadlines.

All members put in equal amount of work into the project report and the same amount of hours into research and team meetings. The group has met for an average of 8 (ten) hours a week during the past five weeks and every member has also put in an average of 6 (six) hours a week into research on their own personal time. During Part I: Research and Design of the Senior Design Project, equivalent to Fall semester, an estimated 340 (three hundred and forty) hours.

4. Engineering Design and Analysis

4.1 Cost Analysis

Below you can find the budget and expected cost for the design and manufacturing of Panther Killer

Table 3 - Expected Expenses

Expected Expenses		Insert # of	
Description	Amount	Periods	Total
Chassis Frame:			
Material	$250.00	1	$250.00
Labor	$500.00	1	$500.00
Miscellaneous	$50.00	1	$50.00
Total Chassis Expenses			$800.00
Body Shell			
Foam Sheets	$200.00	2	$400.00
Paper Masked Sheets	$35.00	4	$140.00
Carbon Fiber Mat	$100.00	3	$300.00
Polyester Molding	$50.00	1	$50.00
Acetone Gallon	$20.00	1	$20.00
Miscellaneous	$100.00	1	$100.00
Manufacturing	$600.00	1	$600.00
Total Body Shell Expenses			$1,610.00
Engine			
Engine Cost	$500.00	1	$500.00
Ignition System	$50.00	1	$50.00
Miscellaneous	$50.00	1	$50.00
Total Engine Expenses			$600.00
Brake System			
Brake discs	$150.00	2	$300.00
Pedals	$20.00	2	$40.00
Tires	$80.00	3	$240.00
Disc Hub	$50.00	2	$100.00
Miscellaneous	$50.00	1	$50.00

Total Brake System Expenses			$730.00

Steering System			
Steering Wheel	$70.00	1	$70.00
Steering Key	$2.00	1	$2.00
Steel Rod	$15.00	1	$15.00
Hollow shaft	$30.00	1	$30.00
Bushings	$6.00	1	$6.00
TieRod Plate	$35.00	1	$35.00
TieRods	$7.00	1	$7.00
TieRod Brackets	$30.00	1	$30.00
Steering Spindle Arms	$90.00	1	$90.00
Bolt 1	$1.00	1	$1.00
Nut 1	$1.00	1	$1.00
Bolt 2	$1.00	1	$1.00
Nut 2	$1.00	1	$1.00
Miscellaneous	$30.00	1	$30.00
Total Steering System Expenses			$319.00
Travel Expenses			
Flights	$400.00	6	$2,400.00
Vehicle Shipping	$800.00	1	$800.00
Hotel Stay	$100.00	4	$400.00
Total Travel Expenses			$3,600.00
Fundraisers			
Fundraiser 1	$100.00	1	$100.00
Fundraiser 2	$100.00	1	$100.00
Fundraiser 3	$100.00	1	$100.00
Total Money Fundraised			$300.00
Sponsors and Donations			
Sponsor 1		1	$-
Sponsor 2		1	$-

Donation 1		1	$-
Total Money Donated			$-
TOTAL EXPENSES			*$7,659.00*
TOTAL REVENUE			$300.00
TOTAL COST	$7,359.00	3	$2,453.00

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