CHAPTER 1

Introduction

1.1 Background of Study

The principle of the Shell Eco-marathon is simple: to design and build a vehicle that uses the least amount of fuel to travel the farthest distance. This project will revolves around automotive background, specifically on the engine, transmission and fuel system.

1.2 Problem Statement

In designing a car, fuel consumption is always a major consideration. For an example, modern gasoline engines have an average efficiency of about 25 to 30% when used to power a car. As discussed, due to the lack of efficiency of the engine, fuel is not fully used and utilized. This will not only waste the fuel, but also a waste in terms of environment (pollution) and value for money.

In this market, there are many types of engine available, varying from their specs and performance. Our aim is to find an engine that is light and most efficient in both fuel-consumption and performance. The main question is, which is the most suitable with our aim?

1.3 Objective & Scope of Study

1.3.1. Objective

To select and design a suitable engine, transmission and fuel system which produce more output with every fuel taking Shell Eco-Marathon's limitation into consideration.

1.3.2. Scope of Study

This project will be specifically on engine, transmission and fuel system selection and optimization. Each system will be analyzed individually, and when linked into a bigger system. These are the specs and scope of each part;

Engine

The engine should be design to be placed outside of the driver's compartment (isolated). Here are the specifications of the engine:

Specification	**Measurement**
Size	small
Cc	low
Performing RPM	low
Number of strokes	4 strokes
Hp (horsepower)	low
Weight	light

Table 1.2.3.1: Engine's scope

Transmission

For the first phase, transmission should be simple and direct. For this project, a small gear and chain will be installed directly to the engine and the back wheel.

Fuel System

- Fuel System should be isolated from the driver's compartment.
- Fuel pump should be designed to be detachable from the vehicle (as stated in the Shell eco-Marathon 2010 rules for measuring purposes)
- Only mechanical pump is permitted which the engine drives.
- The allowable fuel tank can be chosen from 30, 100 or 250cc. (as stated in the Shell eco-marathon 2010)
- For pressurized fuel pump, tank must bear the "APAVE" certification.
- Fuel system must be designed with a valve. (to drain the chamber and to ensure the fuel level goes down the tank)

1.4 Design Requirements

Design requirements were established early in September 2009 to help guide the team in designing the Eco-Marathon vehicle's engine and powertrain. The design requirements set a goal for the total weight of the engine and powertrain, as well as specific goals for the engine, fuel system, and transmission as detailed below.

- The engine will be fuel-injected using 87-octane gasoline as its energy source.

- The powertrain will incorporate a multiple speed transmission to reduce fuel consumption during vehicle acceleration.
- The engine and powertrain will complete the Shell Eco-Marathon competition circuit, requiring only a reasonable amount of maintenance.
- The vehicle will meet all requirements set out in the 2010 Shell Eco-Marathon Official Rules including the following:
  - The powertrain will be equipped with a clutch to immobilize the vehicle without outside assistance.
  - The engine exhaust will be evacuated outside the vehicle body.
  - The fuel system will not be pressurized by an electric fuel pump.
  - The vehicle will have an exterior kill switch to shutdown the engine and isolate the battery in the event of an emergency.

1.5 Feasibility of the Project within the Scope and Time frame

Up to now, the project is feasible within the scope, time and cost. Team has a whole year to produce the car; which is the output of the project. Up to now, team had done with the initial stage, which is the familiarization and design stage. For the next 6 months from now, the fabrication and optimization process will take place. This project would be the best project within it's study scope as it involves all the engineering processes (designing, fabrication), as well as hand-on activities.

CHAPTER 2
LITERATURE REVIEW

2.1 Basic Theory of 4 stroke engine

The four strokes refer to intake, compression, combustion (power), and exhaust strokes that occur during two crankshaft rotations per working cycle of the gasoline engine and diesel engine.

The cycle begins at *Top Dead Center* (TDC), when the piston is farthest away from the axis of the crankshaft. A stroke refers to the full travel of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC) [1].

- **INTAKE stroke:** On the *intake* or *induction* stroke of the piston , the piston descends from the top of the cylinder to the bottom of the cylinder, reducing the pressure inside the cylinder. A mixture of fuel and air is forced by atmospheric (or greater) pressure into the cylinder through the intake port. The intake valve(s) then close.
- **COMPRESSION stroke:** With both intake and exhaust valves closed, the piston returns to the top of the cylinder compressing the fuel-air mixture. This is known as the *compression* stroke [1].
- **POWER stroke:** While the piston is close to Top Dead Center, the compressed air–fuel mixture is ignited, usually by a spark plug (for a gasoline or Otto cycle engine) or by the heat and pressure of compression (for a diesel cycle or compression ignition engine) [1]. The resulting massive pressure from the combustion of the compressed fuel-air mixture drives the piston back down toward bottom dead center with tremendous force. This is known as the *power* stroke. which is the main source of the engine's torque and power.
- **EXHAUST stroke:** During the *exhaust* stroke, the piston once again returns to top dead center while the exhaust valve is open. This action evacuates the products of combustion from the cylinder by pushing the spent fuel-air mixture through the exhaust valve(s) [1].

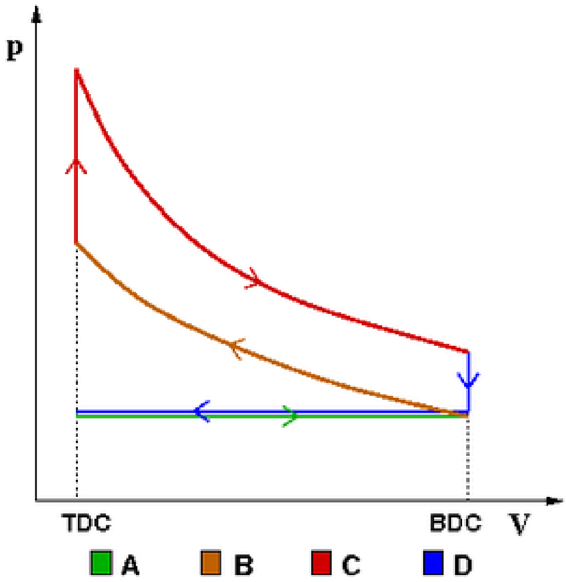


Figure 2.1.1: The idealized four-stroke Otto cycle p-V diagram

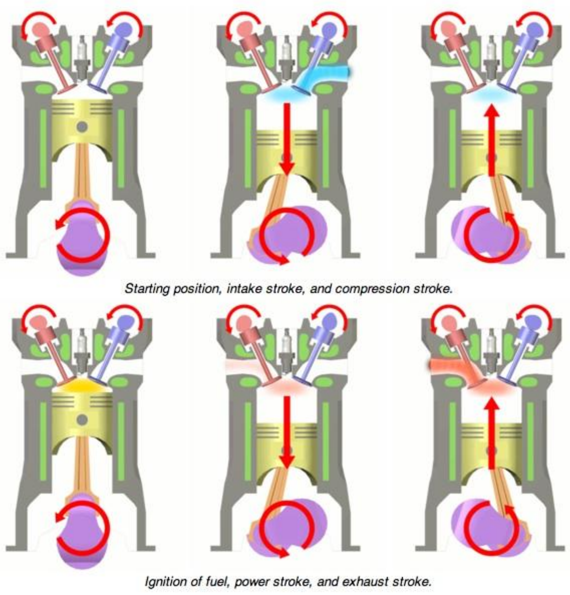


Figure 2.1.2: How a 4-stroke engine works

Another popular engine is the 2-stroke engine. It was widely use until the 4-stroke engine was introduce. It has some advantages against the 4-stroke engine, such as [2]:

- Has more get-up-and-go because it fires once every revolution, giving it twice the power of a four stroke, which only fires once every other revolution.
- Packs a higher weight-to-power ratio because it is much lighter.
- Is less expensive because of its simpler design.
- Can be operated in any orientation because it lacks the oil sump of a four stroke engine, which has limited orientation if oil is to be retained in the sump.

But then again, Shell Eco-Marathon rules had not allowed teams to use this engine due to *their high emission level and the high decibel noise generated*, which is not favored for the competition [3]. Here's are a few disadvantages of the 2-stroke engine [2]:

- Faster wear and shorter engine life than a four stroke due to the lack of a dedicated lubricating system.
- Requires special two stroke oil ("premix") with every tank of gas, adding expense and at least a minimal amount of hassle.
- Heavily pollutes because of the simpler design and the gas/oil mixture that is released prior to, and in the exhaust (also creates an unpleasant smell).

- Is fuel-inefficient because of the simpler design, resulting in poorer mileage than a four-stroke engine.
- Has a high-decibel *whine* that may exceed legal noise limits in some areas, depending on the product and local applicable laws.

Team is concern to find an engine, which can combine both advantages for both 2-stroke engine and 4-stroke engine; small & light weight, simple, and generate more power at the same time fuel efficient, which leads us to two choices of engine; Yamaha C3 Scooter Engine and Honda GX35.

2.1.1 Yamaha C3 Scooter Engine

The 49cc Yamaha XF50 engine is designed for fuel economy and comes stock with an electronic fuel injection system. The engine is compact and lightweight, while incorporating many of the advanced technologies used on larger displacement engines. The engine requires modification as it comes preassembled with a CVT scooter transmission, electric fuel pump, and liquid cooling system. With modifications to these components, the Yamaha XF50 should provide an excellent base engine for our design and for future Eco-Marathon teams to improve on [4]. Due to cost and availability issue, this engine cannot be implemented as our engine for the competition.

There are two teams using this engine, which are Mines University and Indiana High School. Mines scored at 9th place while Indiana was marked 1st place in Shell Eco Marathon America.

Both teams did not specify whether they had modify engine or not, but since the engine itself is using a fuel injection as the carburetion method, it would definitely saves fuel.

Nevertheless, another team from Dalhousie University had chose to use this engine lass December in favor of Honda GX 35. [4]

2.1.2 Honda GX35 Engine

Many teams which had participated in the competition are using Honda GX 35 as their engine. They will then modify the engine according to their preference.

Some goes with Fuel Injection, some modify the engine to be HICE (Hydrogen Internal Combustion Engine). Here are a few examples of Universities which modifies their Honda GX35 engine:

- Dalhousie Universities (modify their engine to use plasma ifnition system)
- Isfahan University of Technology (using fuel injection method)
- Liceo Scientifico Statale G.B Quadri Vicenza (using Econogreen).

In year 2005, Honda had provided 20 GX31 engine to Shell Eco-Marathon UK Schools Initiative. This shows that Shell has confidence with Honda's engine and believes it could be the platform for students to design better fuel consumption engine based on GX31 engine [6].

The 2009 Dalhousie Eco-Marathon team used a 35cc Honda GX35 engine. The Honda engine is small and light, but produces its maximum power and torque at high engine speeds (over 6,000rpm), where fuel consumption is also high. As well, the vehicle as currently designed has been proven underpowered for initial acceleration, partly due to the insufficient torque available from the engine. Further, the engine is designed for use with a carburetor and would require significant modifications to convert to a fuel injection system. These limitations warranted research into stock fuel injected engines suitable for the application and the decision to pursue a new base engine for the 2010 Eco-Marathon vehicle [4].

Another advantage of GX31 /GX35 /GX 50 engine is that it is 360° inclinable 4 stroke engine. Thus, in the future, if we were to change the position of the engine, it would not be a problem since it works in any angle [5].

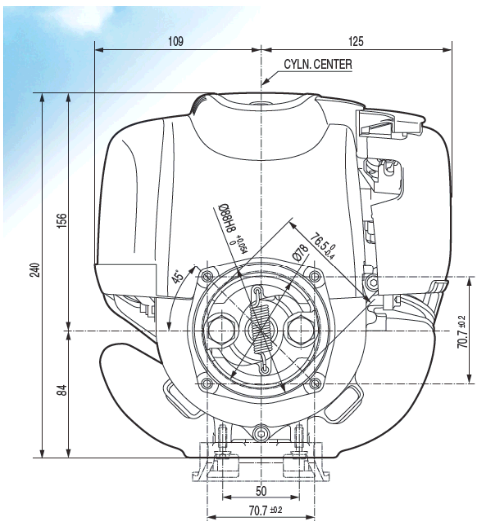


Figure 2.1.2.1: Dimension of the engine

Figure 2.1.2.2: Honda GX 35

2.2. Basic theory of Transmission

In order to transmit rotational motion generated by the engine efficiently, a transmission must be there. The transmission transmits the power generated to the wheel to move the car. For further understanding, the concept of the transmission used for the competition is like the go-kart concept, which consists of the drive shaft attached to the cart's main axle. As the gear rotates, it spins the drive shaft, which in turn spins the go-kart's axle. The spinning of the drive shaft transfers torque from the motor's piston to the axle and ultimately to the go-kart's wheels. Most go-karts have rear-wheel drive systems, which mean that the drive shaft is attached to the go-kart's rear axle. The rear axle provides power to the cart's rear tires, which propel the cart forward [7].

A gear train is a set or system of gears arranged to transfer rotational torque from one part of a mechanical system to another [8].

Gear trains consists

- Driving gears - attached to the input shaft
- Driven gears/Motor gears - attached to the output shaft
- Idler gears - interposed between the driving and driven gear in order to maintain the direction of the output shaft the same as the input shaft or to increase the distance between the drive and driven gears. A compound gear train refers to two or more gears used to transmit motion.

2.2.1 Continuous Variable Transmission (CVT)

A **continuously variable transmission** (**CVT**) is a transmission which can change steplessly through an infinite number of effective gear ratios between maximum and minimum values [9].

Most of teams had implemented this type of transmission as their first consideration. This includes UC Berkeley University and ISFAHAN University of technology (IUT). This contrasts with other mechanical transmissions that only allow a few different distinct gear ratios to be selected. The flexibility of a CVT allows the driving shaft to maintain a constant angular velocity over a range of output velocities. This can provide better fuel economy than other transmissions by enabling the engine to run at its most efficient revolutions per minute (RPM) for a range of vehicle speeds.

2.2.2 Rohloffs Speedhub (a type of derailleur)

Dalhousie University had chosen to implement this type of transmission, as it is the most efficient in their transmission choices. They had considered the CVT, simple derailleur and pocket bike transmission. In the market, it is proven to be the most efficient of all the derailleur.

Figure 2.2.2.1 Rohloff Speedhub

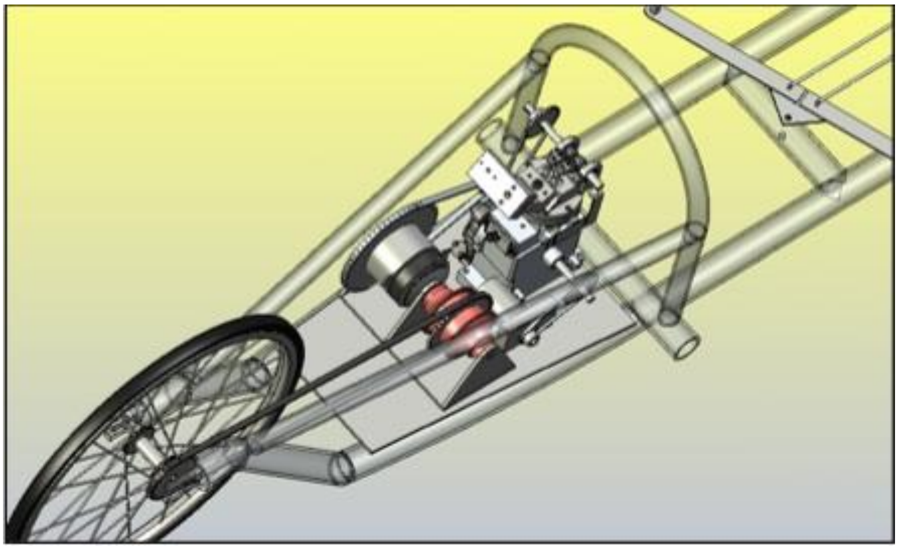


Figure 2.2.2.2 Drivetrain assembly of the Dalhousie Team

2.2.3 Direct transmission

Direct Transmission is the type of transmission used which transmit the power from engine directly from the engine. The power can be increase/ decrease depends on the gear ratio of the engine. There are also a few teams that use direct transmission in their cars.

Here are a few pictures of the teams, which use this method in the last Shell Eco-Marathon Americas 2007 Competition.

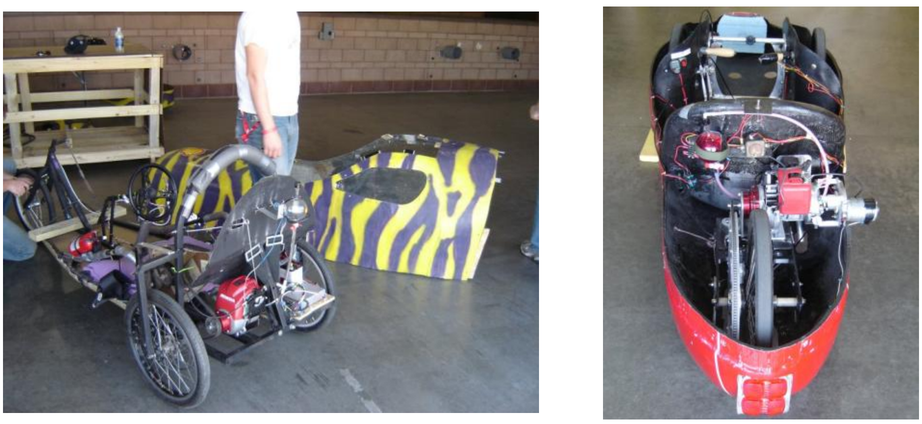


Figure 2.2.4 Linear Transmission (Wheels are directly linked to the engine)

2.3. Examples of engine and drive train mechanism

For the this years Shell Eco-Marathon, for both European and Asia's version, all teams has their own strategy and mechanism for their car. In this literature review, engine & transmission specification will be elaborated.

2.3.1 IUT Ville d'Avray (France)

From the 4th to 6th of June on the Nogaro race track (France) Institute of Technology (Institut Universitaire de Technologie) of Ville d'Avray took part in Challenge Educ-Eco, the first French mileage competition which replaced the European Shell Eco- marathon on this track [10]. They won the 1st prize by consuming the equivalent electrical energy of a 2 minute use of a hair-dryer to cover 25 km. Here are the specification of their engine & transmission:

- Engine: *Honda NPS50* gas engine: 4-stroke cycle engine, 50 cc. 4 valves, EFI , compression ratio of 12.
- Transmission: Direct /1-stage transmission with 13/129 ratio, 8mm pitch chain, chain tensioning at rest by engine tilting with a tensioner

Figure 2.3.1.1: Direct transmission of the car

Figure 2.3.1.2 Honda NPS50 gas engine

Figure 2.3.1.3 The car design

2.3.2. SEMAC (Shell Eco-Marathon Albi Club)

This team is from Ecole des Mines of Albi (France). The are using hydrogen fuel cell to power-up their car [11]. For the transmission, they are using direct transmission, equipped with a tensioner so that the chain does not slip easily.

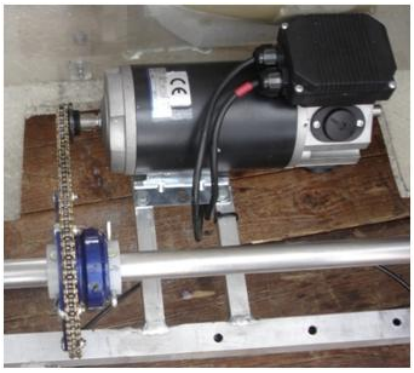


Figure 2.3.2.1; The fuel cell

2.3.3 CALSMV

CALSMV is UC Berkelly's Super Mileage Team (University of California). The team chooses to use Briggs & Stratton (B&S) lawn edger engine as a powerplant, which has number of serious disadvantages [12]. These are the disadvantages:

- It displaces approximately 150cc, which is more than is necessary to power the car.
- It is a flathead engine with the intake and exhaust valves in the engine block, which are actuated with a nylon camshaft.
- There is no pressurized lubrication system
- The crank rides on main bushings instead of bearings
- The ignition is a fixed-advance magneto system
- Usage of carburetor

In order to increase efficiency of the engine, a EFI system named Alpha-N, built by Fancy Carol Team, the world longest record holder for the team, is installed to the engine.

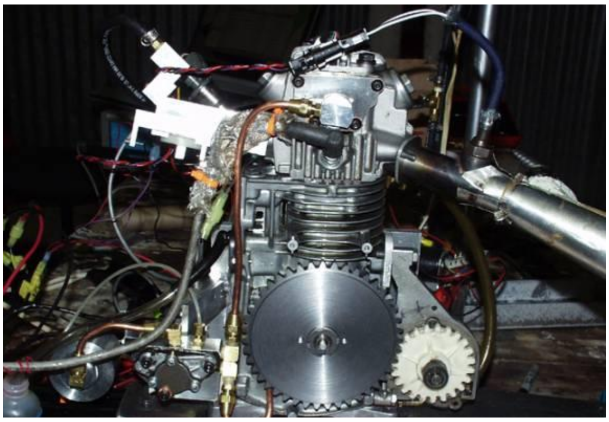


Figure 2.3.3.1: The engine

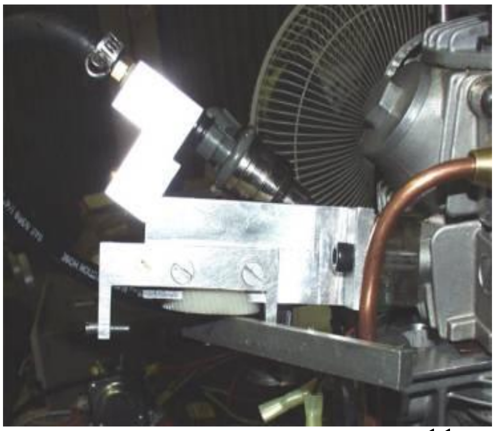


Figure 2.3.3.2: Alpha-N installed to the

2.3.4. USM Shell Eco-Marathon (Gen 1 & Gen 2)

This is the first time for the team to participate Shell Eco Marathon. The Malaysia Team uses Honda GX-35 as their engine and direct transmission from the engine to the rear wheel [13]. The have assembled their car, but problem lies in the transmission, braking system and the chassis. The chain that connects the engine and sprocket was misaligned, caused the chain to fall off from its position and displaced the engine [13]. The braking system does not work and the chassis is too heavy. There is no modification done to the engine yet.

Figure 2.3.4.1: Test running the car

2.3.5. The 2010 Dalhousie Eco-Marathon

For 2010 Shell Eco-Marathon, the team focuses on changes on the engine itself. The transmission mechanism remains the same, that is, using the two speed chain transmission [14].

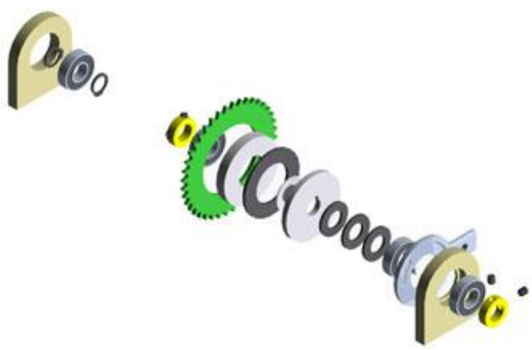


Figure 2.3.5.1: Exploded view of clutch components

Figure 2.3.5.2: Yamaha XF50

The implement Yamaha C3 engine, Yamaha XF50 engine instead of Honda GX-35; the engine they used last year. It is a 50cc engine, powered by EFI [14].

2.3.6. Isfahan University of Technology

Honda GX-35 is chosen to be the engine of the car. As of now, team is implementing the same strategy as last year [15]; which is to use Honda GX 35, equipped with electrical fuel injector and CVT transmission.

Figure 2.3.6.1: Engine Testing on their

2.3.7 Autonomie 3D

This team is the winner of European Shell Eco-Marathon 2009 for Diesel category. Their car had run 2154km per liter of fuel, equivalent to 1930 km per liter. The team had used Diesel Halz 1B20 Engine, and direct transmission, using a centrifugal clutch [16].

Figure 2.3.7.1: Direct transmission mounted to the rear wheel and the engine

Figure 2.3.7.2: The car design

2.3.8 Sapu Angin1 (Indonesian Team-ITS)

Sapu Angin, the car's name is an Indonesia ITS team. For their engine, they are using an unknown 25 CC, 4 STROKE OHC VALVETRONIC [17]. The engine is powered by EFI, whereas the drive train is fixed to sprocket chain system.

2.3.9 ME 4202 Capstone

Team from LSU Collage, ME 4202 Capstone has also participated the competition [18]. Unfortunately, no specification of engine or transmission is provided.

Figure 2.9.1: the car design

2.3.10 Rashtriya Vidyalalya College of Engineering

This team from US had achieved 180km per liter of fuel. The engine type is not dislosed, but it runs using carburator, thus, consuming more fuel. The transmission system is a special type of CBD, a name which they claim they can't disclose now, and has been imported from the US [19]. It has to be integrated with the engine, and gives a very high reduction of gears which gives us very high engine efficiency and adds to the mileage.

Figure 2.3.10.1: Team's car and members

2.3.11. UCBC Supermileage team

UCSB’s Super Mileage Vehicle averaged 500 miles per gallon and had a top speed of 45 miles per hour [20]. The vehicle placed 11th out of 32 teams in their first year, which is very good considering their car was quite a bit faster than the other cars. They bought a little scooter brand new, ripped it to shreds day one, and took the pieces they needed [20]. They had to switch the motor backwards so they had to completely change the transmission configuration to make the car run with the motor in backwards. No specification on the engine nor transmission was made.

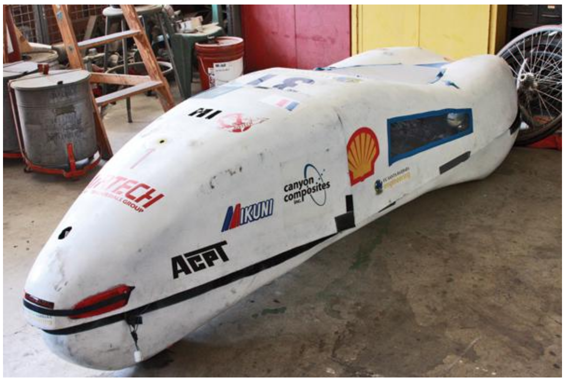


Figure 2.3.11.1: The car's design

2.4. Electrical Fuel Injection (EFI)

The improvement of carburetor to Electronic Fuel Injection (EFI) has been decided through data analyze from other teams who enter Shell Eco Marathon such as Isfahan University of Technology, Fancy Carol, University of Massachusetts Amherst and more. It proven that EFI enhance fuel consumption and efficiency of the engine [23].

The basic theory behind the injection system was as follows, the alpha-N system uses the throttle position and engine speed to estimate an engine load. Based on this theoretical load, it sets a particular injector (open) time. When the system is in closed loop mode, the controller takes the oxygen sensor’s rich/lean signal and adjusts the theoretical injector time until the desired air/fuel ratio is achieved. This system works by "train" the computer what to do in a given situation during dynamometer testing. For every possible combination of throttle position and rpm, the tuner determines the appropriate ignition timing and fuel delivery to yield max power but not incur explosion or denotation. The computer just remembers all this in the form of maps which are stored on a chip. When it sees a certain combination of rpm and throttle position in the field, the engine act as programmed in dynamometer. So it explains how throttle position and RPM are the two dominant input parameters to the engine computer [21].

The alpha-N system is chosen since it used by the Fancy Carol which holds the world Super Mileage Record of 4079.1km/L. Below is the picture of Fancy Carol team with alpha-N system.

Figure 2.4.1: Fi-M

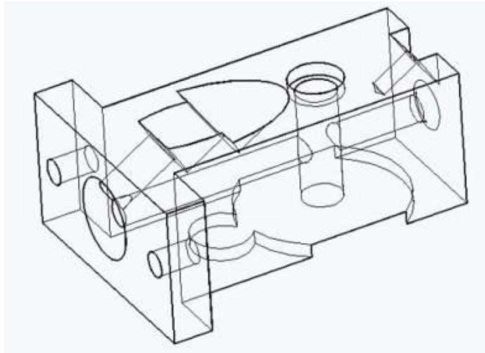


Figure 2.4.2: Wireframe drawing of alpha-N system

The Fi-M digital is the new development version of Fi-M that team Fancy Carol has used in the race. It is designed only for Shell Eco Marathon. It is very simple and easy setting by the digital dial. Injection control is just only for idling and wide open throttle. The fuel injection control of Fi-M digital is completely same as old Fi-M, but the "Meter function" is equipped as a new feature in "Fi-M digital controller". It makes the injection control even better and easy to use during the race [21]. Below are the main features of Fi-M digital:

- Simple fuel injection system for ECO MARATHON vehicle.
- Only two settings to determine "Injection Time", "WOT" (WOT: Wide Open Throttle) and "Idle".
- Pump control function.
- Revolution speed limiter.

Moreover, there are some additional features of Fi-M digital where the controller can display the following engine and vehicle data in “Meter Function”[21]:

- Amount of fuel [cc] ([Sum of the fuel injection time] * [The injector flow rate])
- Runing Distance (Trip) & Total runing distance (ODO).
- Fuel consumption. (Runing Distance / Amount of fuel [km/L])
- Vehicle speed. [km/h]
- Engine speed. [r.p.m.] and Engine hour meter.[h.m.s]
- Supplied voltage. [Volts] & Temperature. [degree Celsius]

CHAPTER 3

Methodology

3.1 Methodology

Up to now, the methodology remains the same. The project has been progressing within its time frame.

NOTE: The blue colored stands for the complete stages. The "*updated" stands for updated method/activates which was not included in the previous planning report to further enhance the flow of the project.

- **Determining the theoretical requirement**
  - Literature review and Shell Eco-Marathon Rules and Regulation 2010 must be read before hand. This is to determine the basic requirements and to have a head start by analyzing what others had done in previous races.
- **Comparison**
  - There will be various types of mechanism and strategy used in this competition. Thus, comparison must be done in order to find the best method to be used. Once set, designing process is next.
- **Designing**
  - Designing includes sketching, first draft and 3D drawing.
- **Simulation (Engine Testing)**
  - Simulation is to simulate the design before the actual fabrication takes place. Variable such as the engine output, input, speed of the vehicle can be obtained from simulation.
- **Fabrication & assembly**
  - Once the drawing is done, we can now fabricate and assemble the components.
- **Final Drawing *updated**
  - The final drawing will now be produce. The initial designing process takes consideration only on the requirements and a limited exposure to the market's part availability. Thus, the initial stage of designing

might vary due to many factors during the fabrication and assembly process.

- **Modification and optimization**
    - If the system works (once linked together), frequent testing must be done. If there's any problem, the part must be modified. If it works, parts are ready for the second phase, which is optimization process

3.2. Project Activities

These activities will also in reference with the team. Activities may subject to change (add / drop) in the future.

NOTE: The blue colored stands for the complete stages. The "*updated" stands for updated method/activates which was not included in the previous planning report to further enhance the flow of the project.

Determining the theoretical requirement

- Literature review

Comparison

- Literature review

Parts familiarization *updated

- Team gets together and discuss on the functions and parts of the available parts (e.g. engine) to give team a clearer view on what are we working on.

Designing

- 3D Drawing using Catia V6

Fabrication & assembly

- Assembling all parts using necessary tools.
- Welding

3.3 Key Milestone

Our key milestone would be to finish the first phase design (before optimization) and ensuring it can reach to the finishing line.

3.4 Gantt Chart *updated

Please refer to Appendices.

3.5. Tools required (softwares)

There are list of software that must be use for this project such as:

Designing and simulation: ADAMS, CATIA V6

Engine performance softwares: Avl puma, cp cadet V12, motec and dataq pro

CHAPTER 4

Estimated Result and Discussion

4.1 Result

4.1.1 Selection of Engine

From the literature review, 2 engines are chosen for this project. The engine that meets most of the specification will be chosen for the project.

Engine	*Honda GX 35*	*Yamaha C3 2009*
Engine specs	35cc Mini 4-Stroke OHC (Overhead Cam)	49cc liquid-cooled, OHC 4-stroke single; 3-valves, 18hp
Compression ratio	8.0 : 1	12.0:1
Starter	Manual	Electric
Net Horse Power Output	1.0 kW (1.3 HP) at 7,000	5HP, 3.8Kw, @ 8,000rpm
Net Torque	1.6 Nm (1.2 lbs ft) at 5,500 rpm	4.6 Nm (3.4 Ft Lbs Torque) @ 6,500rpm
Weight (estimate)	3.46 kg	4.01 kg
Fuel Preparation	Carburator	Electronic fuel injection
Cost	RM1100	RM6000 + tax

Table 4.1.1.1: Detailed comparison between the cars.

Criteria	Weight factor
Cost	0.50
Weight	0.25
Performance	0.35

Table 4.1.1.2: Weight factor

	Honda GX 35		Yamaha C3	
	Score	Rating	Score	Rating
Cost	10	5.00	5	2.50
Weight	7	1.75	3	0.75
Performance	4	1.40	8	2.80
Weight property index	8.15		6.05	

Table 4.1.1.3: Weight property index

4.1.2. Design of the engine

Here is the engine 3D CAD design that will be installed in the car later on:

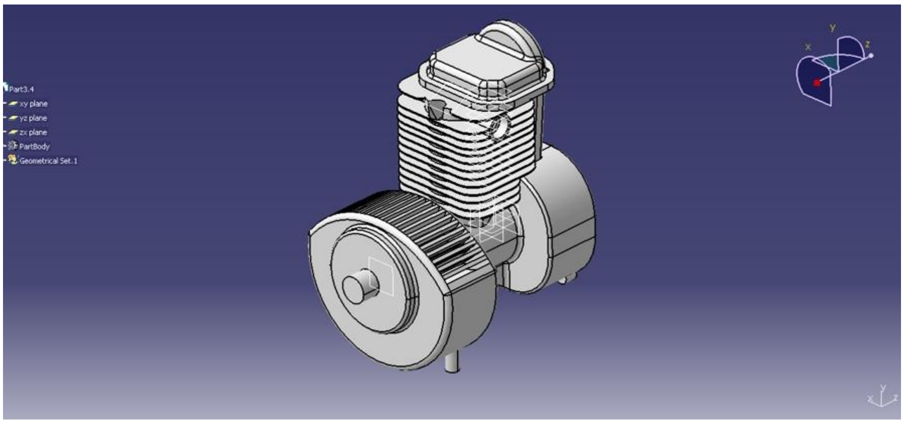


Figure 4.1.2.1: GX 35 engine after dismantling the exhaust, fuel tank and mounting

This is the overall design on how does the car looks like when it is assembled.

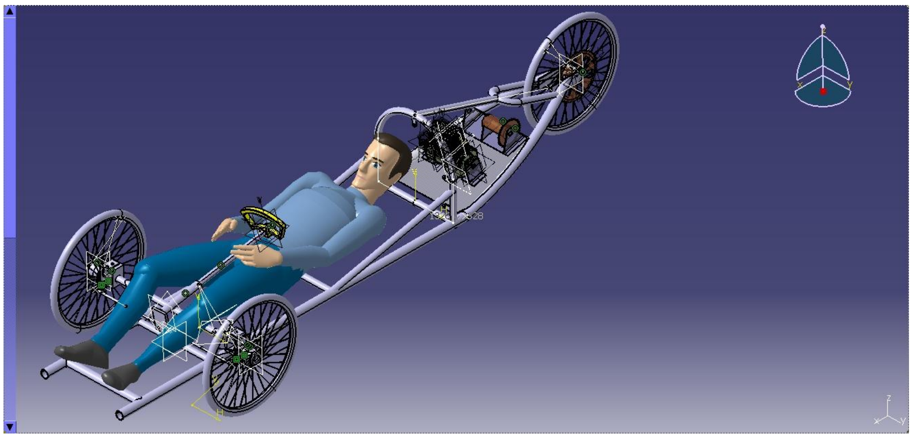
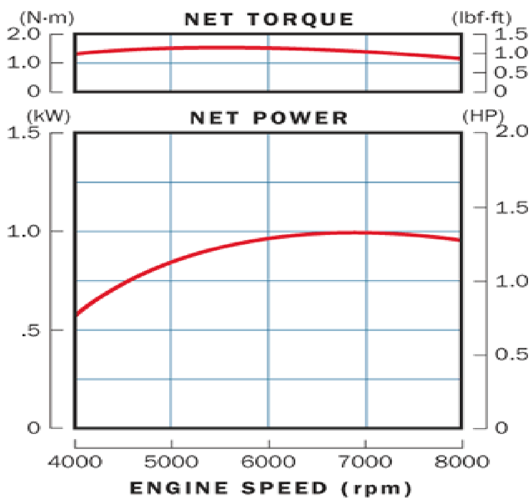


Figure 4.1.2.2: The overall design of the car

4.1.2.3 Output / performance of the engine

- **Performance Curve**



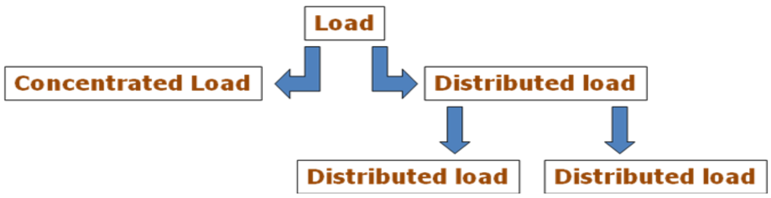
GX35

Table 4.1.3.1: Performance curve of the engine

The power rating of the engine indicated in this document is the net power output tested on a production engine for the engine model and measured in accordance with SAE J1349 at 7000 rpm. Mass production engines may vary from this value. Actual power output for the engine installed in the final machine will vary depending on numerous factors, including the operating speed of the engine in application, environmental conditions, maintenance and other variables.

4.1.4. Force acted on to engine and transmission mounting

The mounting of engine and transmission must be strong and durable enough to sustain the static load force transmitted by the engine and transmission system and is able to endure the vibration transmitted as well [22]. Here are the static forces:



Parts	Mass (kg)	Weight (N)
Engine Dry Weight (New)	3.3	32.406
Engine Dry Weight (without casing, fuel tank and clutch)	2.5	24.55
Electric starter sprocket	0.04	0.393
Engine Output Sprocket	0.05	0.491
Engine Input Sprocket	0.05	0.491
Friction Clutch	2	19.64
Electric Motor	0.2	1.964

Table 4.1.4.3: Transmitted static load onto the mounting

Based on the suitable physical properties, availability and cost, **ASTM A36 Steel** is selected. This is the physical property of the material:

Physical Properties	Metric	Comments
Density	7860kg_m3	
Mechanical Properties		
Tensile Strength, Ultimate	400 - 550 MPa	
Tensile Strength, Yield	250 MPa	
Elongation at Break	20.0 % 23.0 %	in 200 mm In 50 mm.
Modulus of Elasticity	200 GPa	
Bulk Modulus	140 GPa	
Poisson Ratio	0.266	
Shear Modulus	1.3 GPa	

Table 4.1.4.2: Material Properties of the steel

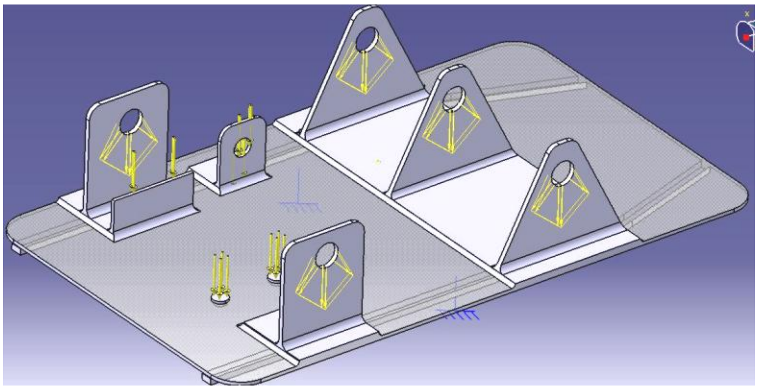


Figure 4.1.4.1: Load applied onto the mounting

4.1.5. Modification of engine

Clutch cover modification to fit sprocket

The shaft of the engine, which serves as the output of the engine is located within the clutch casing, thus it is hard to install a sprocket to the shaft. Thus, modification must be made to the clutch in order to install the sprocket.

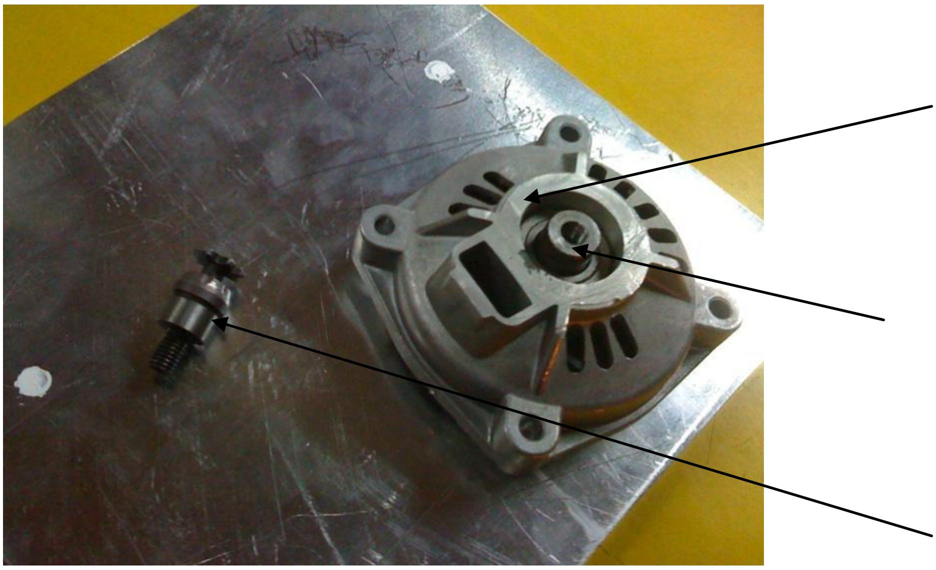


Figure 4.1.5.1: Modified clutch

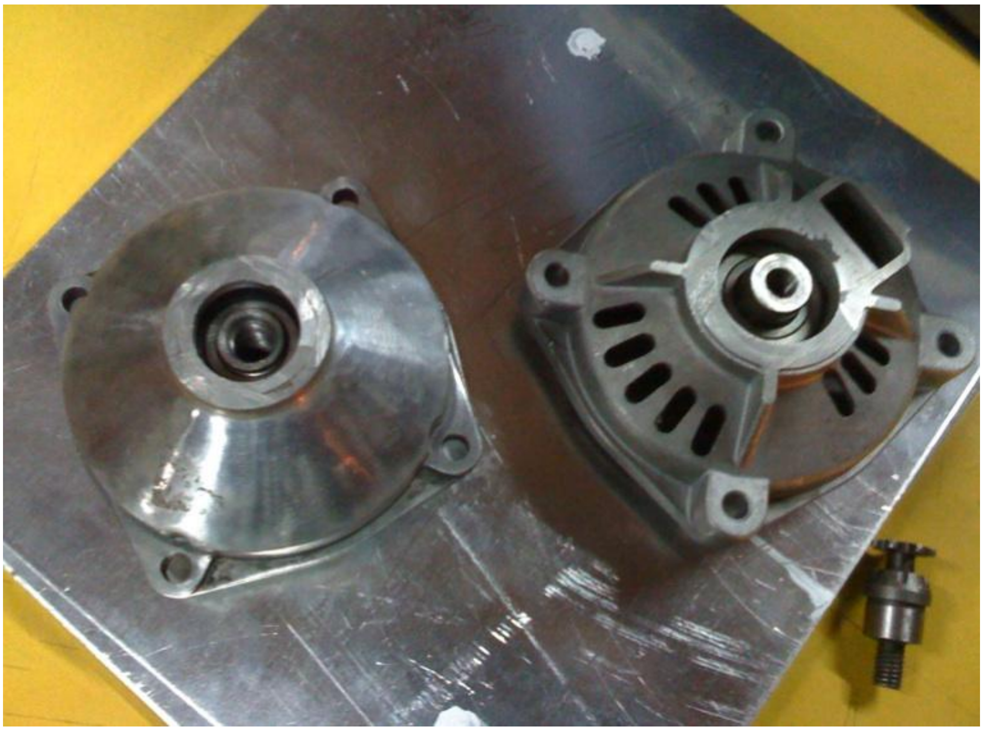


Figure 4.1.5.2: Difference between the clutch covers

But, we had also considering using this mini-bikes clutch cover (modified) instead, as is proven reliable even after modified and the size of sprocket to be installed are bigger (thus more teeth).

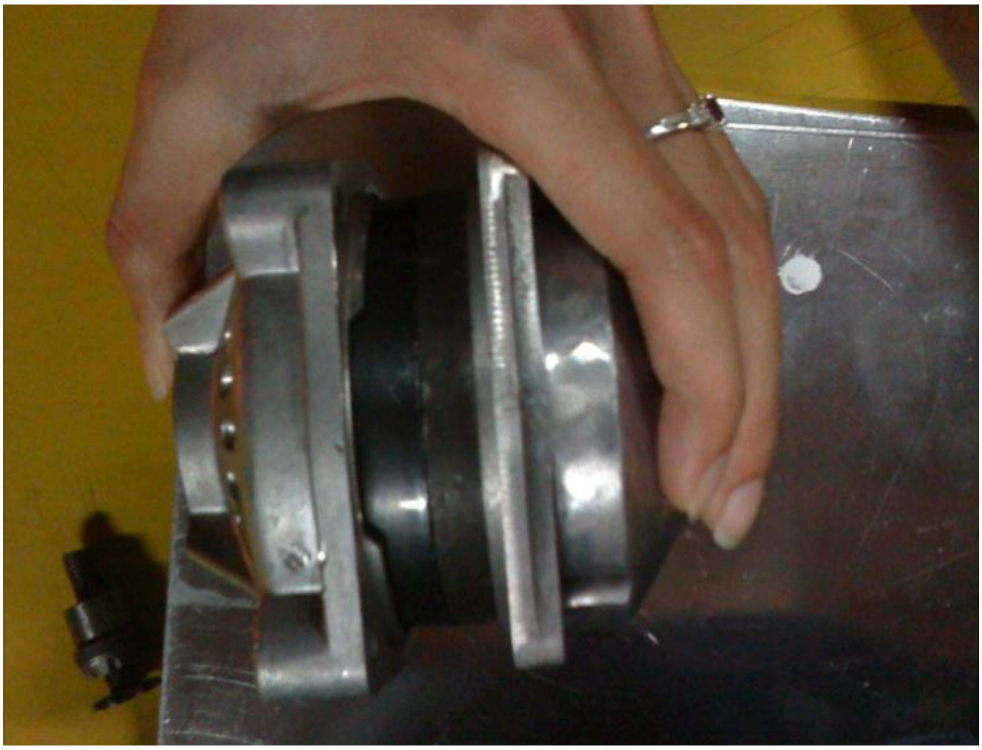


Figure 4.1.5.3: Same sizes, easy to assemble

Modification to the clutch shoe due to clutch slip

Previously, the internal clutch in the engine slips due to insufficient friction between the clutch shoe and the cover. To avoid slip in the clutch, we create some “groove” to the clutch shoe. The concept is the same to a tire thread or shoes, where the thread will increase friction between the two surfaces, hence, less slips occurs to the clutch. This will increase efficiently to the energy delivered to the car from the engine.

Figure 4.1.5.4: The clutch with the 'thread'

4.2 Transmission

4.1.2 Selection of Transmission

From the literature review, 2 engines are chosen for this project. The engine that meets most of the specification will be chosen for the project.

Transmission	*CVT*	*Rohloff Speedhub*	*Direct Transmission*
			

Table 4.2.1.1: Selection of Transmission

Criteria	Weight factor
Cost	0.50
Weight	0.17
Performance	0.23

Table 4.2.1.2: Weight factor

	CVT		Rohluff Deraillíur		Direct Transmission	
	Score	Rating	Score	Rating	Score	Rating
Cost	7	3.50	2	1.0	9	4.50
Weight	7	1.19	9	1.53	9	1.53
Performance	6	1.38	9	2.07	5	1.15
Weight property index	6.07		4.06		7.18	

Table 4.2.1.3: Weight property index

From the previous result, linear and direct transmission has been chosen to be used, as it is the easiest and cost-effective for this stage. A sprocket will be attached to the engine shaft (on the clutch cover) and the other sprocket is attached to the rear wheel. Linking the sprockets is a chain.

4.2.2. Chain drive versus belt drive

As with belt, chain drives are used to transmit rotational motion and torque from one sprocket/ shaft from one to another smoothly, quietly, and inexpensively. Chain drives provides the flexibility of a belt drive with the positive engagement feature of a gear drive [24]. Therefore, chain drive is well suited for application with large distances between the respective sprockets, slow speed and high torque [24].

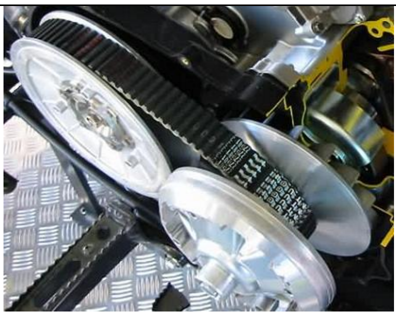
Transmission type	*Belt drive*	*Chain drive*
		

Table 4.2.2.1: Type of transmission drive

Criteria	Weight factor
Cost	0.15
Resistance to slippage	0.20
Effective for low speed	0.10
Durability	0.20
Reliablility	0.20
Low tensional load to the sprocket	0.15

Table 4.2.2.2: Weight factor

	Belt drive		Chain drive	
	Score	Rating	Score	Rating
Cost	10	1.50	9	1.35
Resistance to slippage	5	1.00	7	1.40
Effective for low speed	4	0.40	8	0.80
Durability	5	1.00	9	1.80
Reliablility	6	1.20	9	1.80
Low tensional load to the sprocket	4	0.60	8	1.20
	5.70		8.35	

Table 4.2.2.3: Weight property index

Chain drive has a higher weight property index, thus team decided to choose the chain drive as the transmission drive type. Here are a few advantages of the chain drive [24]:

- Less expensive than the gear drives
- No slippage, as with belts and provide a more efficient power transmission.
- Flexible shaft centers distances, whereas gear drives are restricted.
- More effective at lower speeds than belts.
- Lower loads on the shaft bearings because initial tension is not required as with belts.
- Longer service life and do no deteriorate with factors such as heat, oils, or age as do belts.
- Require minor adjustments, whereas belts require frequent adjustments.

4.2.3. Transmission design

The engine and the transmission is link as shown in the design:

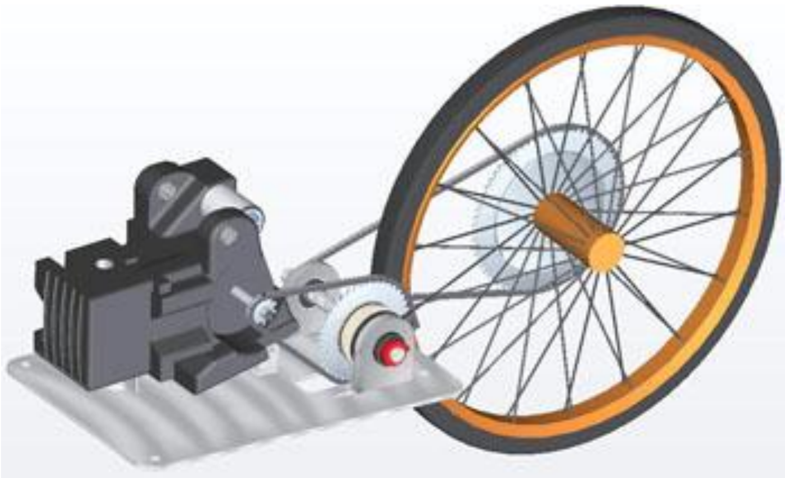


Figure 4.2.3.1: GX 35 engine and the transmission system

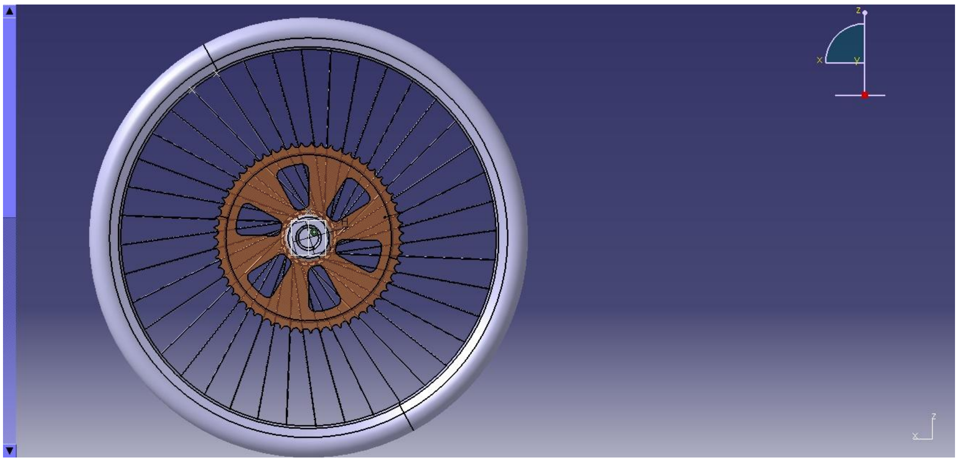


Figure 4.2.3.2 Rear wheel attached with the second sprocket

This is the overall design on how does the car looks like when it is assembled.

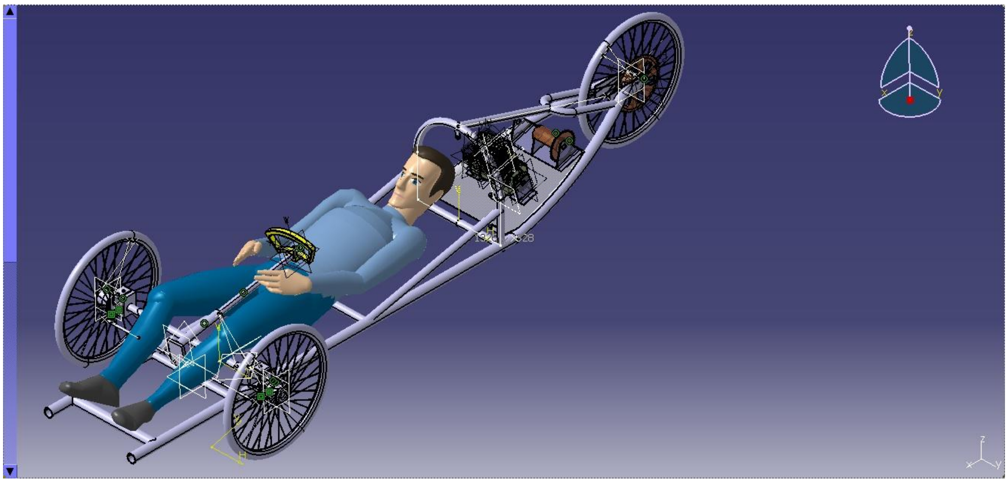
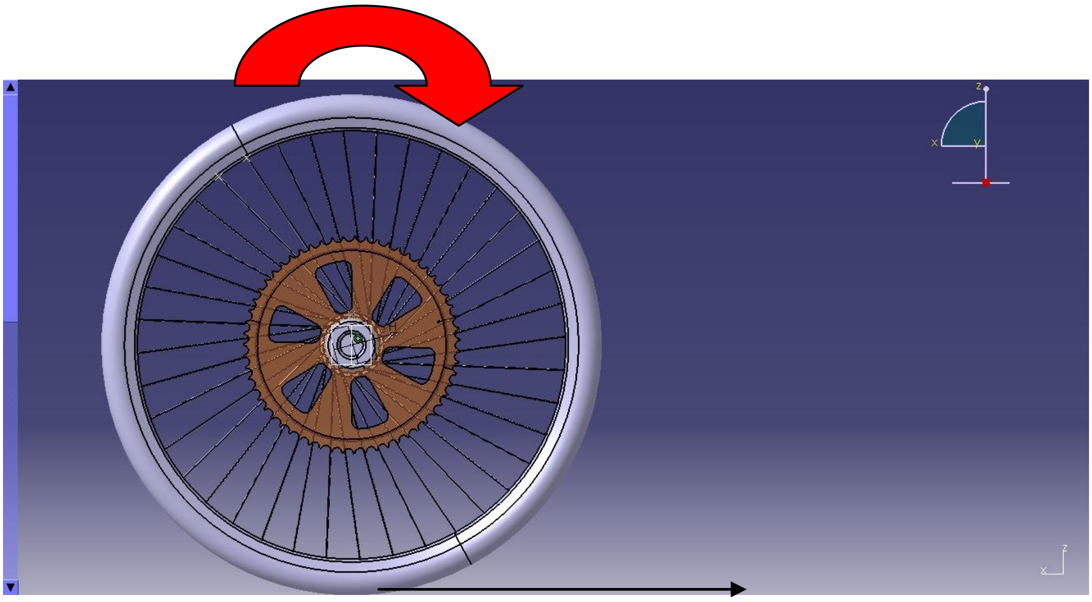


Figure 4.2.3.3: The overall design of the car

4.2.4 Transmission Calculation



Engine RPM at maximum torque = 6200rev/min

Desire Speed of the car is 35km/h

= 35 x (1000m/3600s)

= 9.722 m/s

Relationship between Angular Velocity and Linear Velocity v

Given a fixed speed v and radius r, then:

$v = \omega r$

$\omega = v \times (1/r)$

$\omega = 9.722 m/s \times (1/0.255 m)$

$\omega = 38.125 rad/s$

1 rev = 2π radians

RPM = 38.125 (rad/s) x (1/2p) (rev/rad) x 60s/1min

=364.07 rpm (rpm of the tire)

Desired gear ratio is:

= 6200/364.07 = 17.9, approximately 18.

Based on availability of the sprocket:

- First gear A, n=8
- Second gear B, n=40
- Third gear C, n=15
- Fourth gear D, n=54

$$\text{Gear ratio} = \frac{\text{No. of teeth on "B"}}{\text{No. of teeth on "A"}} \times \frac{\text{No. of teeth on "D"}}{\text{No. of teeth on "C"}}$$

Gear ratio = (40/8)*(54/15) = 18

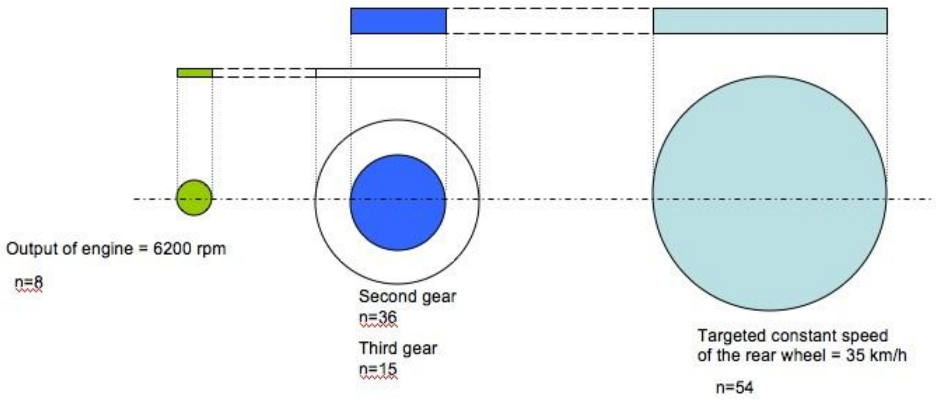


Figure 4.2.4.1: Gearing system of the car

Other possible equations

Chain velocity

$$V = Npn$$

N = number of sprocket teeth

P = chain pitch

n = sprocket speed (rev/s)

Lenght of the chain to be used

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

4.2.5. Modification/Addition to Transmission system

In order to avoid the chain from falling again, chain tensioner is installed to the fourth sprocket [14]. This will increase the tension in the chains, thus will leave minimal gap that does not allow any tolerance for the chain to fall of the sprocket again.

Figure 4.2.5.1: The chain tensioner and the location its been installed

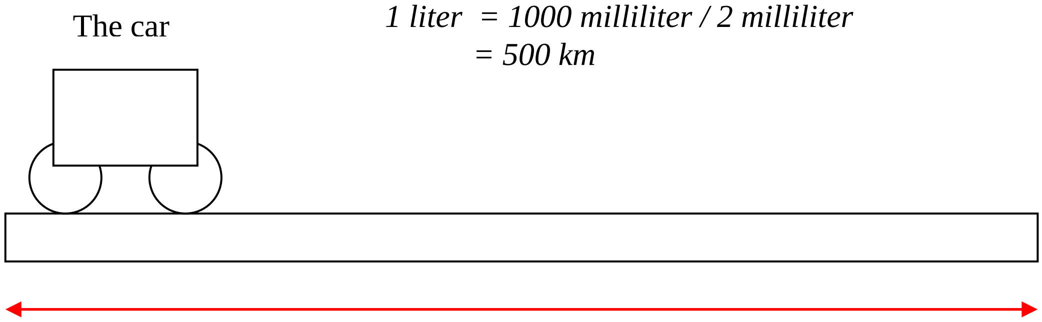
4.3 Fuel efficiency (distance traveled) calculation

To measure the fuel consumed for 1 litter of fuel, team took this steps to calculate the distance traveled:

1. The starting point is set.
2. The volume of the fuel in the fuel tank is ensured to be 1 liter
3. Once the car starts to travel, it will continuous to travel the agreed distance (for example 1 km)
4. Once the car is stop, the remaining fuel is calculated.
5. From there, team will know what is the fuel consumed
   - I liter - fuel remaining = fuel consumed
6. Thus, the fuel consumed is equivalent to 1 km; from there, team can calculate the distance the car can travel for 1 liter.

Example:

1km = 2 milliliter of fuel is consumed
1 liter = 1000 milliliter / 2 milliliter
= 500 km



4.4 Discussion

The design requirements introduced at the beginning of the project to guide us through the design process. A summary of the status of these requirements is presented in the table below is based on the final design and results of the Shell Eco-Marathon competition.

As shown in the table, the project almost met all of the design requirements. A brief discussion on the engine and transmission section in section 4.3.1 and 4.3.2 which contributes to the success.

Item	**Requirement**	**Status**
Fuel System	Fuel injected	Fuel injected (currently installed)
Fuel efficiency	>1000km	>500km (running carburetor, EFI is yet to be installed and the kilometer is assumed to be more after the installation
Transmission	Direct	Direct
Reliability	no major problems during competition	Currently test running without any major problems
Eco-Marathon Regulation	Meet all regulation	All is met, down with the casing for the transmission only

4.4.1 Engine Progress

The engine is now stabile and running smoothly. Team is currently in attempt of installing the EFI (Alpha-N) that arrives since last week. The engine can carry the car load and the engine manage to drive the car at 50 km/h. Fabricating another new mounting for the engine, installation of damper beneath engine mounting, and installation of a new exhaust reduces the vibration issue.

During the installation of the EFI, team found out the clearance of the engine is very small, thus makes the installation of EFI system more risky and complicated. Modification needs to be done for the bore to make space for the EFI.

The electrical system for the engine (start and stop button etc) will be installed once the EFI is fitted into the engine.

4.4.2 Transmission system progress

Previously, there are a few problems occur for the transmission, regardless all four gears are mounted to their respective position. Team manage to solve the following problems:

- The chain is not tension enough.
    - Chain tensioner is introduced.
- The fourth sprocket mount is not aligned with the third sprocket.
    - The whole transmission is reinstalled and the angle is corrected.
- Loud noise developed by the first sprocket to the second sprocket due to meshing of sprocket and the chain.
    - Lubrication is added.

Currently, no problem is occurred with the transmission.

CHAPTER 5

Conclusion and Recommendation

5.1 Conclusion

Up to now, the Honda GX 35 is able to drive the car and does not create major problems (break down etc). With the small size and lightweight, it does not add in much weight to the car hence less force to is needed. With further optimization team can ensure the fuel consumed is lesser. Transmission is stabile, thus more test run must be made to ensure the reliability for both system continues.

We are proud to conclude that the engine and power train design, as described above, has met most of the design requirements submitted at the start of the design process. With the funding from the Mechanical Engineering Department and respective sponsors, the current budget for the engine and transmission is approximately RM11,000++. During test run, the car manage to achieve 500km per liter of fuel; that is without any modification onto the engine (EFI system), which will result in more mileage once the whole car is completed.

The engine and power train developed for this project should provide a solid basis for future UTP SEM (Shell Eco Marathon) to build on. The updates made to the engine and fuel system offer many opportunities for modifications that will further improve fuel efficiency. Overall, the project was a success for our team and is capable of providing continued success to students who choose to participate in the Shell Eco-Marathon or any race events in the future.

5.2 Recommendation

Although the engine and power train described in this report were stabile, there are several potential areas for improvement that future UTP SEM could investigate. First, if team decided to continue to use the same engine, an upgraded ignition system with a plasma arc sparkplug could be used to give more efficient combustion in the engine. Also, blocking one of the two ports could modify the existing injector, halving the volume of fuel sprayed in each injection cycle [14]. If modification were made to the injector, a user programmable engine control unit may be required to maintain reliable operation. A MegaSquirt or equivalent engine control unit package would allow future teams to create a fuel map, optimizing fuel consumption across the full operating range of the engine.

Alternatively, team can implement different engine for the competition; which is already equipped with the EFI system such as Yamaha C3 engine.

New transmission can also be implemented. Team can fabricate a new sprocket for the car, which only has two sprocket; hence the direct transmission. The new sprocket will be more aligned perfectly, at the same time constructed with lightweight yet durable material (alloy and such). The transmission will run smoothly, less energy loss and less weight force onto the car.

If team is ready for something more advance, multiple speed transmission can also be implemented. This can reduce the fuel consumption in a way during the start, lower gear is used, and when speed is smooth and stabile, higher gear is introduced.

5.3 Acknowledgements

The team would like to acknowledge the individuals and organizations listed below for their assistance in making this project possible.

- Ir. Dr Masri Baharom
- Ap. Dr Abd. Rashid b Abd aziz
- Mr Azman Zainuddin
- T. Nagarajan
- Mechanical Department Individuals
- Our Family and Friends

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