ENGINE SELECTION AND DESIGN OF POWERTRAIN FOR SIMPLE VEHICLE FOR OPTIMUM FUEL CONSUMPTION

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CERTIFICATION OF APPROVAL

Engine selection and design of powertrain for simple vehicle for optimum fuel consumption

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Approved by,

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CERTIFICATION OF ORIGINALITY

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

MOHAMMAD FARHAN BIN HARON

ABSTRACT

This report is about the study of the powertrain system and engine selection of a simple vehicle for optimum fuel consumption. The project is about selecting the best engine, and determining the best component that suit the objectives of this project. The study of the other projects to familiarize with the components has been made. Modeling with computer aided software has been done to get the configuration of the drive system. A prototype of the powertrain has been fabricated to test the effectiveness, reliability, flexibility and durability of the system that have been designed. A few tests have been done to verify the fuel consumption and also the performance of the prototype. Data logger (DL2 RACING TECHNOLOGY) has been used to get a better value of the fuel consumed by the prototype. Average fuel consume by this prototype is 60.08km/liter. The engine and powertrain design satisfies all of the requirements from Shell Eco-Marathon 2011. Recommendation for future UTP Shell Eco-Marathon teams are presented based on our observations and experiences throughout the term and at the competition.

ACKNOWLEDGEMENT

First of all, I would like to deliver my greatest gratitude to Allah S.W.T for His blessing; I had managed to complete my final year project. I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend my sincere thanks to all of them.

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INTRODUCTION

1.1 Background of study

The Shell Eco-marathon is a competition where it challenges students to build a vehicle that uses the least amount of fuel to travel the farthest distance. This project will be fully about the vehicle engine and transmission. The selection and design steps will revolve throughout this project. Preliminary method is to observe and familiarize with UTP SEM 10 prototype. While getting some comments from lecturers, seniors and technicians about the prototype to plan some of the area that can be improve.

1.2 Problem statement

While the ability of petroleum engines to maximize the transformed chemical energy of the fuel (their fuel efficiency) has increased since the beginning of the automotive era, this has not necessarily translated into increased fuel economy or decreased fuel consumption, which is additionally affected by the mass, shape, and size of the car, and the goals of an automobile's designers, which may be to produce greater power and speed rather than greater economy and range.

In this project, the main concern is about the efficiency of the transmission to deliver the engine power. For a simple car, the major issue is the related gear ratio when climbing uphill, during cruising and during moving downhill. All those conditions needs difference sets of gear ratio in order to cope with the forces acting on the vehicle. For instance, during climbing hill, the gear ratio needs to be big enough as the road gradient enlarged the static force on the vehicle.

Making the Shell Eco Marathon 2010 UTP team (SEM1 and SEM2) and the rules and regulation of the competition as the reference, there are a few problems need to be taken care of.

- The vehicle need to have a neutral gear which means the vehicle is not moving at the engine starts (idle speed).
- Both car of previous SEM, uses single speed transmission, to get a better mileage, variable speeds is most suitable.
- Their (SEM1 and SEM2) transmissions perform well when climbing uphill but not when moving downhill and cruising
- The chain breaks due to clutch failure prior to the competition rules that is the vehicle cannot move at engine idle speed.
- Clutch installed is not suitable with the competition rules and regulations.

1.3 Objective and scope of study

1.3.1. Objective

Our main objectives for this project:

- To fabricate a drive system with variable transmission.
- To produce a light weight drive system.
- To build a drive system with higher reliability, efficiency, and durability.
- To design a drive system that able to perform gliding movement.

The main point is the variable speed transmission which need is one of the crucial elements in term of fuel consumption.

Another section is the clutch of the engine. Since the engine of HONDA GX160 using a simple clutch which not designed for the purpose of delivering high performance torque, slipping will be always introduced. This mechanical part will need to be altered properly.

Plus, there has been a comment on the chain system that making so much noise. Due to this, maybe the used of belting system should be considered.

By all this preliminary investigation of pros and cons of each part of the prototype, the feasibility study will be conducted to select all the best part for vehicle's optimization.

Fabrication, material availability and the cost is the part that needed to be focused also on the later stage.

1.3.2 Scope of Study

This project is focused on engine, transmission and fuel system selection, optimization and improvisation. Each system will be analyzed individually, with the fuel economy motive.

The study of transmission on how they suppose to deliver power and how to optimize the equipment of the transmission will be the major study of this project. Engine selection will be based on the capacity, size, dry weight, strokes, availability and cost.

Another scope of study is in the part of designing the powertrain system. Detail design of gearing system, engine mounting and clutch will be conducted also in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

2.1.1 BASIC THEORY OF POWERTRAIN

A powertrain is a system of mechanical parts in a vehicle that first produces energy, then converts it in order to propel it, whether it be an automobile, boat or other machinery. The average person is most familiar with the powertrain of their car, which creates energy in the engine, which is transferred to the transmission. [1] The transmission then takes the power, or *output,* of the engine and, through specific gear ratios, slows it and transmits it as *torque.* Through the driveshaft, the engine's torque is transmitted to the wheels of the car, which, when applied to road, moves the car. Simply put, a powertrain is made up of an **engine, a transmission and a driveshaft**. [1]

2.1.2 BASIC THEORY OF TRANSMISSION

A transmission or gearbox provides speed and torque conversions from a rotating power source to another device using gear ratios. In British English the term transmission refers to the whole **drive train**, including **gearbox**, **clutch, prop shaft** (for rear-wheel drive), **differential** and final drive shafts.[2]

Often, a transmission will have multiple gear ratios (or simply "gears"), with the ability to switch between them as speed varies. This switching may be done manually (by the operator), or automatically. Directional (forward and reverse) control may also be provided. Single-ratio transmissions also exist, which simply change the speed and torque (and sometimes direction) of motor output.[2]

In motor vehicle applications, the transmission will generally be connected to the crankshaft of the engine. The output of the transmission is transmitted via driveshaft to one or more differentials, which in turn drive the wheels.

2.2 POWER – LIMITED ACCELERATION

Power-limited acceleration analysis revolved around with examination of the engines characteristics and their interaction through the powertrain with the influence of external frictions (drag and tire friction).

2.2.1 ENGINES

Engines are the source of the propulsive power of an automobile. The ratio of engine power to vehicle weight is the first-order determinant of acceleration performance. [3] The target performance for our prototype is the low operating rpm at the highest speed of the vehicle.

In achieving the goal, there are several variables that need to be considered. At low moderate speeds an upper limit on acceleration can be obtained by neglecting all resistance forces acting in the vehicle. Using the Newton's second law; [3]

$$Ma_x = F_x \qquad (2.1)$$

Where:

M = mass of the vehicle = W/g

a_x =acceleration in forward direction

F_x =tractive force at the drive wheels

By this relation, the least weight will require the least tractive force at the drive wheels. Least tractive force will lead to less power needed to gain the desired acceleration or speed. The hypothesis of this equation is to get the least vehicle plus passenger weight to achieve optimum engine's power to total vehicle mass ratio.

2.2.2 POWERTRAIN THEORY

Focusing on the target of engines revolution per minute that is low rpm at higher speed, there comes a need on the study of the relation between tractive forces, engine torque, transmission and desired acceleration.[3]

$$T_c = T_e - I_e \alpha_e \qquad (2.2)$$

Where: T_c= torque at the clutch (input to the transmission)

T_e= engine torque at a given speed (from dynamometer data)

I_e= engine rotational inertia

α_e= engine rotational acceleration

The output torque can be approximated by the expression that involved the gear ratio of the transmission: [3]

$$T_d = (T_c - I_t \alpha_e)\, N_f \qquad (2.3)$$

Where T_d= torque output to the drive shaft

I_t= rotational inertia of transmission (as seen from engine side)

N_f= numerical ratio of the transmission

The last stage is where the torque delivered to the axles to accelerate the rotating wheels and provide tractive force at the ground is amplified by the final drive ratio with some reduction from the inertia of the driveline components between transmission and final drive. [3]

$$T_a = F_x r + I_w \alpha_w = (T_d - I_d \alpha_d) N_f \qquad (2.4)$$

Where T_a= torque on the axles

F_x=tractive force at the ground

r= radius of the wheel

I_w= rotational inertia of the wheels and axles shafts

α_w= rotational acceleration of the wheels

I_d= rotational inertia of driveshaft

α_d= rotational acceleration of driveshaft

N_f= numerical ratio of the final drive

These co-related expressions in transmitting the power from the engine to the wheels can be combined into: [3]

$$F_x = \frac{T_e N_{tf} \eta_{tf}}{r} - \{(I_e + I_t)N_{tf}{}^2 + I_d N_f{}^2 + I_w\}\frac{a_x}{r^2} \qquad (2.5)$$

Where N_{tf}= combined ratio of transmission and final drive

η_{tf}= combined efficiency of transmission and final drive

Knowing the tractive force, we can now predict the acceleration performance of a vehicle. We had to add up a few more external forces such as the expression: [3]

$$Ma_x = \frac{W}{g}a_x = F_x - R_x - D_A - R_{hx} - W\sin\emptyset \qquad (2.6)$$

Where R_x= rolling resistance forces

D_A= aerodynamic drag force

R_{hx}= hitch (towing force)

$\emptyset$= inclination angle of road

Also

$$\omega_d = N_f\omega_w \qquad \text{and} \qquad \omega_e = N_t\omega_d = N_t N_f \omega_w \ (2.7)$$

After we the wheel rotational speed, ω_w we can find the translational velocity of the vehicle.[3]

$$V_x = \omega_w . r \qquad (2.8)$$

Reviewing back to term of that is the combined ratio of the transmission and final drive, which is what the objective is about. To calculate which is the best gear ratio combination for our purpose of low operating rpm since we are desired in making a variable transmission gearing system.

By this equation [3]

$$- \qquad (2.9)$$

And neglecting the inertia losses [3]

$$\overline{\qquad\qquad} \qquad (2.10)$$

We can predict the suitable gear ratio after we decide on the value of desired engine torque , forward vehicle's acceleration , and inclined angle of the road Ø.

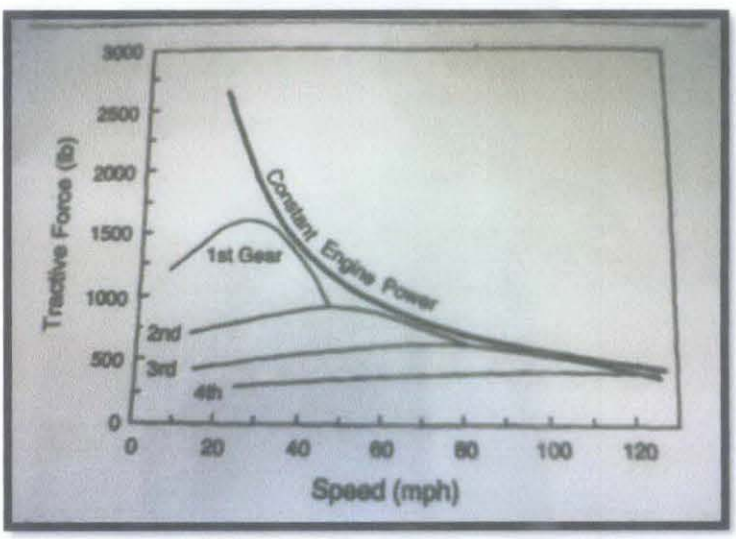


Figure 2.2.2.1: tractive effort-speed characteristics for a manual transmission.

2.3 ENGINE CANDIDATES

2.3.1 HONDA GX35

Figure 2.3.1.1 HONDA GX35

Specifications

Model	GX 35
Engine type	Air cooled 4-stroke single-cylinder OHC petrol engine
Bore x stroke	39 x 30 mm
Displacement	35.8 cm^3
Compression ratio	8.0 : 1
Net power	1.0 kW (1.3 HP) / 7 000 rpm
Max. net torque	1.6 Nm / 0.16 kgfm / 5 500 rpm
Ignition system	Transistorised
Starting system	Recoil
Fuel tank capacity	0.63 l
Fuel cons. at rated power	0.71 L/hr - 7 000 rpm
Lubrication	Crankcase pressure driven
Engine oil capacity	0.1 l
Dimensions (L x W x H)	198 x 234 x 240 mm
Dry weight	3.33 kg* *w/o clutch

table 2.3.1.1 Specification of GX35

The Honda GX35 engine a mini 4 stroke engine with 35cc capacity. This engine only weight less than 3.5kg but produces its maximum power and torque at high engine speeds (over 6000rpm). The major drawback of this model is, it comes with carburetor system where it becomes less feasible for fuel economy motive. Honda creates the world's first 360° inclinable 4-Stroke engines.

There's been an idea of installing the CVT with this engine but it will need further investigation and modification on the compability of the clutch, output shaft and the CVT itself.

There are few of the SEM participants using thing engine that are Isfahan University of Technology, Liceo Scientifico Statale G.B Quadri Vicenza, Institut Teknologi Sepuluh and Universitas Indonesia team.

2.3.2 HONDA GX160

Features Specs Performance Curve

Engine Type	Air-cooled 4-stroke OHV
Bore x Stroke	68 X 45 mm
Displacement	163 cm3
Net Power Output*	4.8 HP (3.6 kW) @ 3,600 rpm
Net Torque	7.6 lb-ft (10.3 Nm) @ 2,500 rpm
PTO Shaft Rotation	Counterclockwise (from PTO shaft side)
Compression Ratio	9.0 : 1
Lamp/Charge coil options	25W, 50W / 1A, 3A, 7A
Carburetor	Butterfly
Ignition System	Transistorized magneto
Starting System	Recoil Starter
Lubrication System	Splash
Governor System	Centrifugal Mechanical
Air cleaner	Dual Element
Oil Capacity	0.61 US qt. (0.58 L)
Fuel Tank Capacity	3.3 U.S. qts (3.1 liters)
Fuel	Unleaded 86 octane or higher
Dry Weight	33 lbs. (15.1 kg)

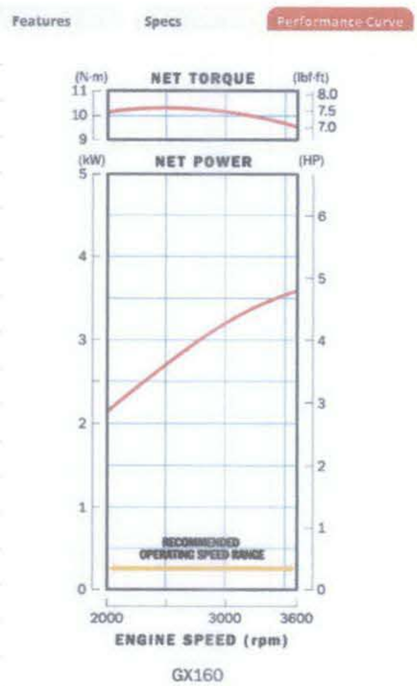


Table 2.3.2.1 HONDA GX160 specifications.

The HONDA GX160 engine is aair-cooled 4-stroke OHV engine. This engine is a powerful engine which delivers 3.6 kW at 3600rpm. The net torque is 10.3Nm at 2500rpm which is ten times more power compared to the HONDA GX35. This engine deliver its maximum torque at a low speed of engine rotation..The most noticeable drawback of this engine is the weight that is 15.1kg .

Several teams had used this engine such as UNITEN, SHELL OFFICIAL CAR and UTM.

2.4 TRANSMISSION CANDIDATE

2.4.1 CONTINUOUS VARIABLE TRANSMISSION (CVT)

Continuously Variable Transmissions are transmissions that provide an uninterrupted range of speed ratios, unlike a normal transmission that provides only a few discrete ratios. [4]

Frictional Type

The most common type of CVT is the frictional type, in which two bodies are brought into contact at points of varying distance from their axes of rotation, and allowing friction to transfer motion from one body to the other. Sometimes there is a third intermediary body, usually a wheel or belt.

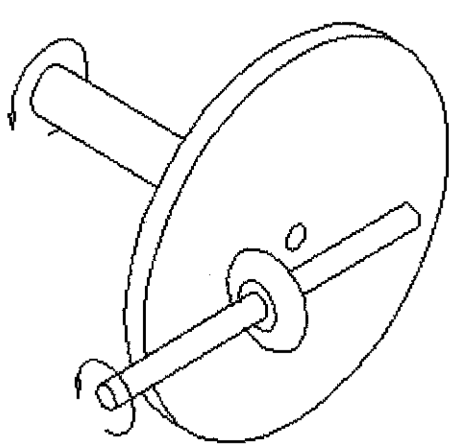


Figure 2.4.1.1: disk and wheel type

The simplest CVT seems to be the "disk and wheel" design, in which a wheel rides upon the surface of a rotating disk; the wheel may be slid along it's splined axle to contact the disk at different distances from it's center. The speed ratio of such a design is simply the radius of the wheel divided by the distance from the contact point to the center of the disk.

Friction plays an important part in frictional CVT designs - the maximum torque transmissible by such a design is:

$$\mathbf{T_{max} = C_f \times F_N \times R_o}$$

where $\mathbf{T_o}$ is the torque output, $\mathbf{C_f}$ is the coefficient of friction between the wheel and the disk, $\mathbf{F_N}$ is the force pushing the wheel into the disk (normal force), and $\mathbf{R_o}$ is the radius of the output wheel or disk. The coefficient of friction depends on the materials used; rubber on steel is typically around 0.8 to 0.9.

Power is lost in two ways: deformation of the components; and differential slip.

Deformation of the components, the larger factor of the two, is caused by high normal forces, and can be minimized by using very hard materials that do not deform much, and materials with a very high coefficient of friction. Differential slip is caused by a large contact area between the rotating components; in this example, the "footprint" of the wheel riding on the disk. The edge of the footprint closest to the axis of rotation of the disk will roll along a smaller radius than the edge furthest from the axis of rotation, causing further distortion of the wheel and the edges of the footprint to slip. Differential slip is minimized by using a hard wheel that produces a small contact area.

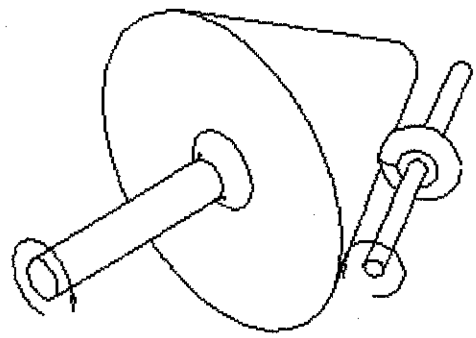


Figure 2.4.1.2: cone and wheel type

Very similar to the "disk and wheel" is the "cone and wheel" design, in which the disk is replaced by a cone. There is little advantage to using a cone instead of a flat disk, except to decrease the differential slip of the contact surface by minimizing the difference in the radius traveled by the inner and outer edges of the contact area. Other designs have used different shapes, but the principle remains the same.

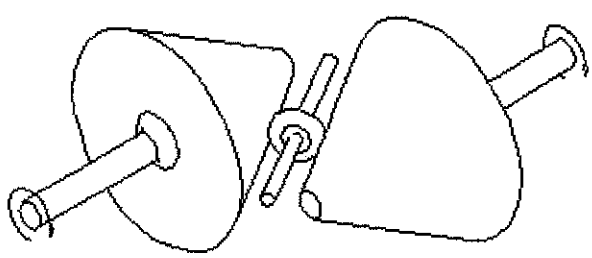


Figure 2.4.1.3: dual cone type

More advanced designs used three bodies instead of two. There are two advantages to using three bodies: an increase in speed ratio range; and a simpler design. However, the range of speed ratios usually crosses unity - for example, it might range from 1:5 to 5:1 - making necessary a secondary gear sets, often a planetary set.

Almost all such designs are based on toroidal contact surfaces, an exception being the "dual cone" design, which only affords the former advantage.

The simplest toroidal CVT involves two coaxial disks bearing annular groves of a semi-circular cross section on their facing surfaces. The spacing of the disks is such that the centers of the cross sections coincide. Two or more (in patent-speak, "a plurality of") idler wheels, of a radius equal to the radius of the cross sections of the grooves, are placed between the disks such that their axes are perpendicular to, and cross, the axes of the disks.

In the image, the speed ratio is varied by rotating the wheels in opposite directions about the vertical axis (dashed arrows). When the wheels are in contact with the drive disk near the center, they must perforce contact the driven disk near the rim, resulting in a reduction in speed and an increase in torque. When they touch the drive disk near the rim, the opposite occurs. This type of transmission has the advantage that the wheels are not required to slide on a splined shaft, resulting in a simpler, stronger design.

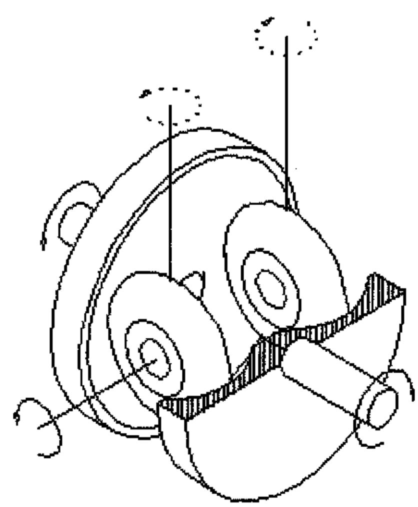


Figure 2.4.1.4: toroidal type

This type of transmission was patented in the U.S. by Adiel Y. Dodge in 1935

Just as the disk CVT evolved into the cone CVT, the toroidal CVT has evolved toward a cone-shape as well. The result is a much more compact transmission. This type is peculiar in that the speed ratio may be controlled by directly rotating the wheels, or by moving them slightly up or down, causing them to rotate and change the speed ratio on their own. This type of transmission is used in the Nissan Micra, Toyota Prius, and Audi A4.

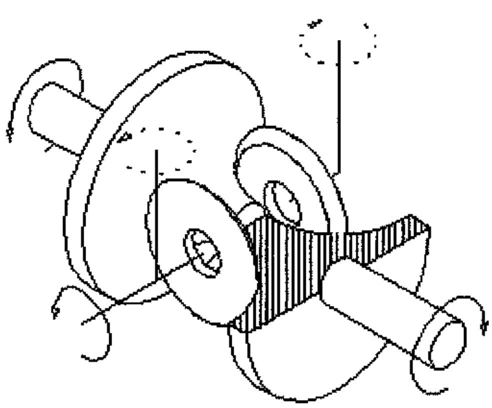


Figure 2.4.1.5: toroidal cone-shape

Variable diameter pulleys are a variation in the theme. Two 20° cones face each other, with a v-belt riding between them. The distance from the center that the v-belt contacts the cones is determined by the distance between them; the further apart they are, the lower the belt rides and the smaller the pitch radius. The wider the belt is, the larger the range of available radii, so the usual 4L/A series belt is not often used in this way. Often special belts, or even chains with special contact pads on the links, are used.

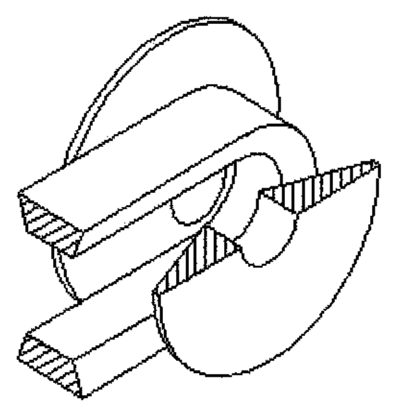


Figure 2.4.1.6: variable diameter pulley

Variable diameter pulleys must always come in pairs, with one increasing in radius as the other decreases, to keep the belt tight. Usually one is driven with a cam or lever, while the other is simply kept tight by a spring. Variable diameter pulleys have been used in a myriad of applications, from power tools to snowmobiles, even automobiles.

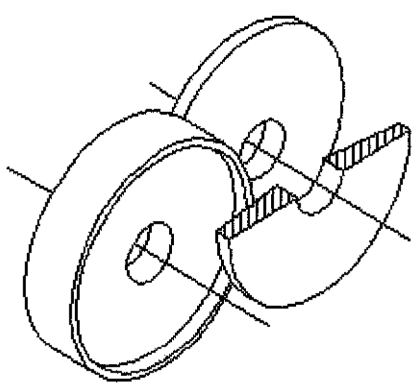


Figure 2.4.1.7: variable diameter friction gear

Variable diameter friction gears are very similar, only with the belt replaced by a wheel with friction surfaces along the sides of its circumference. The two wheels are moved together or apart to control the speed ratio, with the proper distance between the cones being maintained by a spring.

Electrical Type

It could easily be argued that a generator powering a motor through some kind of electronic speed control would constitute a continuously variable transmission. Electrical transmissions have the advantage of great flexibility in layout, as the generator can be located at any distance or orientation with the motor. Furthermore, any excess power generated can be stored in batteries, and drawn upon when high loads are experienced. However, they are heavy and inefficient. A typical generator or motor is only 75% to 80% efficient, so compounding two results in an efficiency of only 56% to 64%. This limits their use to situations where other types of transmissions cannot be used.

Diesel locomotives and some ships use such drive trains, and more recently, "hybrid" gas-electric cars.

Hydraulic Type

A hydraulic CVT is a hydraulic pump driving a hydraulic motor, at least one of which has a variable displacement. If, for example, the pump has a variable displacement, the increasing the displacement will obviously increase the speed of the motor. If the motor has a variable displacement, then the situation is reversed; increasing the displacement will decrease the speed at which it turns, as the volume produced by the pump remains constant. Decreasing the displacement of the motor will likewise increase its speed.

This kind of transmission is used in the Honda Rubicon ATV. It consists of a hydraulic swash plate pump driving a swash plate hydraulic motor. The motor is variable displacement, achieved by controlling the angle of the swash plate.

Most of teams had considered this type of transmission into account of selecting system of the car. This includes UC Berkeley University and ISFAHAN University of technology (IUT).

2.4.2 DIRECT TRANSMISSION (BICYCLE GEARING)

A bicycle gear, or gear ratio, or speed refers to the rate at which the rider's legs turn compared to the rate at which the wheels turn. Bicycle gearing refers to how the gear ratio is set or changed. On some bicycles, there is only one gear so the ratio is fixed. Most modern bicycles have multiple gears, so multiple gear ratios are possible. Different gears and ranges of gears are appropriate for different people and styles of cycling. [6]

Multi-speed bicycles allow selection of the appropriate gear ratio for optimum efficiency or comfort, and to suit the circumstances, e.g. it may be comfortable to use one gear when cycling downhill, another when cycling on a flat road, and yet another when cycling uphill. The set of all possible gear ratios on a bicycle is known as the 'gear range'.

In other word direct transmission is the type of transmission used which transmit the power from engine directly from the engine. The power can be increase or decrease depends on the gear ratio from the engine.

2.4.3 ROHLOFFS SPEEDHUB

The **Rohloff Speedhub** is an epicyclic internal hub gear for bicycles, manufactured by Rohloff AG since 1998. The Speedhub 500/14 has 14 equally-spaced sequential gears with no overlapping ratios and is operated by a single twistgrip. The overall gear range is 526 %, meaning the highest gear is 5.26 times as high as the lowest gear. Individual gear shifts give an increase or decrease of 13.6 %.[7]

The Speedhub is significantly more expensive than competing bicycle gear systems (both hub gears and derailleur gears), but it combines the robustness of hub gears with the gear number and gear range of derailleur gears. [7]

2.5 CLUTCH CANDIDATE

A clutch is necessary to engage and disengage the engine to control movement. As well, a clutch to disengage the engine while starting is a requirement for the Shell Eco-Marathon. Three different clutch designs were considered which centrifugal clutch,

cone clutch, and plate clutch.

2.5.1 Centrifugal clutch

A centrifugal clutch uses the angular velocity of the engine's driveshaft to extend a rotating mass, creating pressure between two friction surfaces to transmit power to an output shaft. At low engine speed, the clutch is disengaged because the centrifugal force is not large enough to cause the rotating mass to move the friction plate outward and lock onto the output mechanism. However, as the engine speed increases the centrifugal force generated by the rotating mass pushes the friction plate to the outer drum, allowing power to be transmitted. Centrifugal clutches allow the motor to develop high torque before engaging and operate at high efficiencies once engaged. This clutch design is same for previous utp team clutch. However, a centrifugal clutch wastes energy before the engine reached the engagement speed. The inherent losses of the centrifugal clutch make it the second popular after friction plate clutch for the Eco-Marathon vehicle.

Figure 2.5.1.1 : Centrifugal Clutch

2.5.2 Cone Clutch

Friction cone clutches offer superior transmission of high torque because the design provides a wedging action that helps the frictional surfaces to bond together. As a result of the wedging action, more force is required to disengage the clutch compared to a friction plate clutch. A cone clutch was eliminated because of its additional size, weight, and design complexity compared to others type of clutch. It is the reason why most of the team not use this type of clutch.

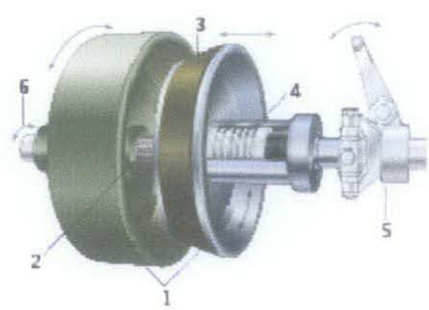


Figure 2.5.2.1 : Cone Clutch

2.5.3 Friction Plate Clutch

Plate clutches operate using a frictional material and plate placed between the driving shaft and the driven shaft. When the two surfaces are pressed together the result is a driving friction that enables the driven shaft to rotate with the driving shaft. Plate clutches are simple to build, inexpensive, and light in weight. The plate clutch can also be engaged and disengaged at any speed, requiring little input force. The friction plate clutch offers many of the features desired in a clutch for the 2010 Eco-Marathon vehicle, making it the best alternative.

2.6 EXAMPLES OF ENGINE AND DRIVE SYSTEM.

IUT Ville d'Avray (France)

Modified series *Honda NPS50* gas engine :

- -4-stroke cycle engine, 50cm3 capacity, 4 valves, modified water cooling, series electronic injection+ignition unit, volumetric compression ratio of 12[8]
- -1-stage transmission with 13/129 ratio, 8mm pitch chain, chain tensioning at rest by engine tilting with a tensioner [8]
- -rear-wheel centrifugal clutch of a series Honda scooter fitted to the crankshaft [8]

Figure 2.6.1 Direct transmission of the car

Figure 2.6.2 Honda NPS50 gas engine

<u>This vehicle has a record of 819km/litre (internal combustion)</u>

INSTITUT TEKNOLOGI SEPULUH (INDONESIA)

Figure 2.6.3 Sapu Angin 1 car

Engine	35CC, 4stroke OHC
Fuel	Gasoline
Transmission	CVT + Sprocket chain system
Fuel system	EFI

<u>This vehicle is on rank 11 on Asia. It s record is 236 km/l(internal combustion category).</u> [9]

UNIVERSITAS INDONESIA SEM 2010

Keris designed in semi-monochoke method, where its body and frame is joined but not in one piece. There is Keris' specification:[10]

1. Body : semi-mono choke
2. Shape : stealth
3. Engine : SOHC Engine, 35 cc, 4 stroke
4. Wheels : 3 (three) wheels
5. Nett weight : 45 kg
6. Transmission : multispeed Bicycle transmission

Figure 2.6.4 3D model KERIS

<u>This vehicle has a record of 146 km/liter.(internal combustion category)[10]</u>

THE 2010 DALHOUSIE ECO-MARATHON ENGINE

The team placed 12th in the prototype gasoline category with 819 mpg, Dalhousie's best result in the Shell Eco-Marathon. The 2010 Dalhousie Supermileage vehicle is powered by a **Yamaha XF50 engine**. The engine was taken from a Yamaha C3 scooter. The modified Yamaha engine is shown below.

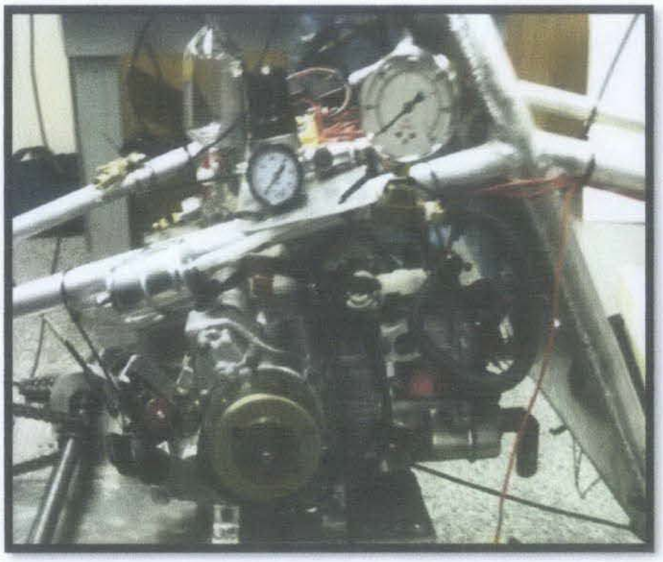


Figure 2.6.5 Modified Yamaha XF50 engine

Figure 2.6.6 Two speed transmission

The 2010 Drivetrain features a **new lightweight clutch** and **two-speed transmission** between the engine and rear wheel. The new clutch is a single friction plate design, integrated with the shaft supports. This design offers a significant weight savings over the "off the shelf" clutch used in last year vehicle.[11]

CHAPTER 3

METHODOLOGY

3.1 Methodology

- **Determining the theoretical requirement**

  The Shell Eco-Marathon rules and regulation must be read carefully before planning on improvisation motive. The literature review will also need to be revised to plan the action for incoming period. This is to determine the basic requirements and to have a head start by analyzing what others had done in previous competitions.

- **Comparison**

  There will be various type of mechanism of powertrain such as the clutch type, transmission system or drive system that is suitable for this prototype. The task is to select the best with regard to fuel consumption, cost and availability. One of the methods is by comparing with the other cars.

- **Design**

  Designing includes sketching, first draft and 3D drawing.

- **Simulation (engine test)**

  This is to simulate the parts before fabrication process comes. Variable such as the engine output, input, and speed of the vehicle can be obtained from simulation.

- **fabrication and assembly**

  Once the drawing and simulation is satisfied, the fabrication and assembly process will take parts.

- **Test run and modification**

  We will test run the prototype and seek for modification if needed after the analyzing the performance.

- **Final drawing**

  The final drawing will be produce once the prototype is finalized.

In order to ensure that the objectives of this project are met by the end of the timeline given, author has come out with the following basic flowchart on the method and basic activities that will be carried out:

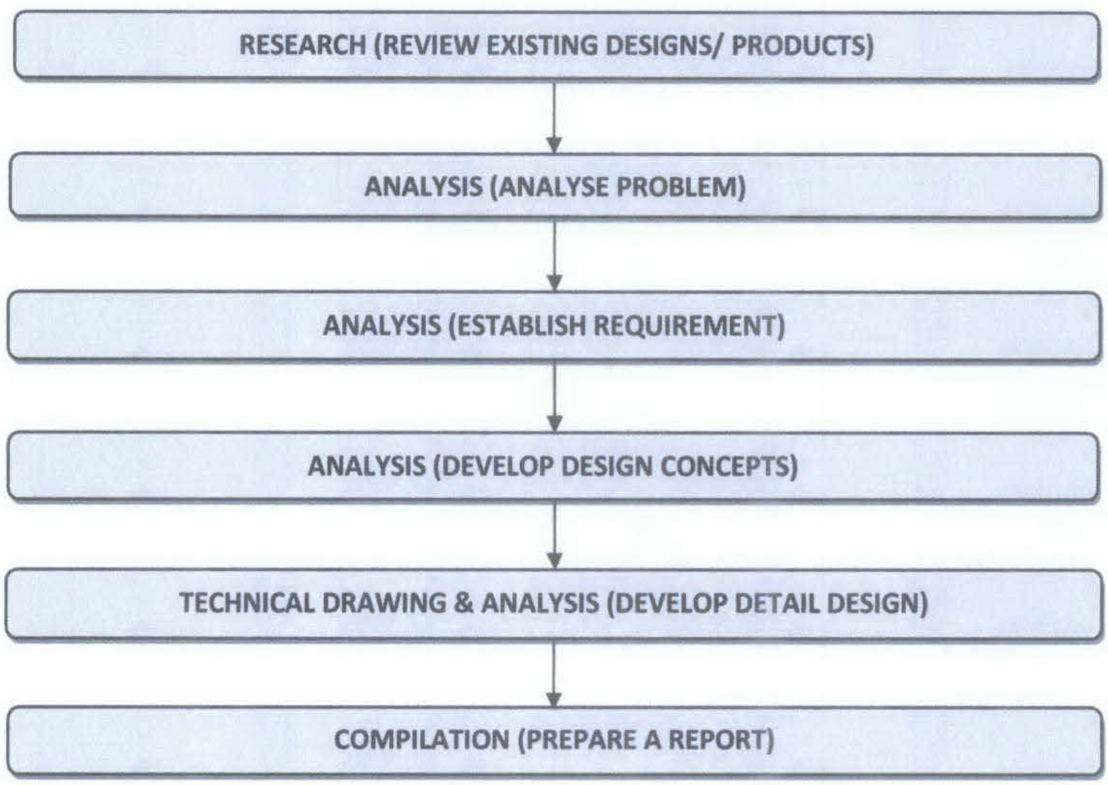


Figure 3.1.1: Basic flowchart on the method used to achieve the objectives of this project

CHAPTER 4

ESTIMATED RESULT AND DISCUSSION

4.1 **Result**

4.1.1 Selection of engine

From the optional study of engine selection, there have come to the best two candidates to be finalized. These engine comparisons are shown below in the selection matrix form.

Engine	HONDA GX35	HONDA GX160
Engine specification	35cc Mini 4-stroke	160cc 4-stroke engine
Compression ratio	8.0:1	9.0:1
Net horse power	1.0 kW (1.3HP) @ 7000rpm	3.6 kW (4.8HP) @ 3600rpm
Starter system	Recoil starter (manual)	Recoil starter(manual)
Net torque	1.6 Nm (1.2 lbs.ft) @ 5500 rpm	10.3 Nm (7.6 lbs.ft) @ 2500 rpm
Weight	3.3 kg	15.1 kg
Fuel preparation system	Carburetor	carbuteror
Cost	Rm 1000	Rm 1200

Table 4.1.1.1 Detail comparison between Honda GX35 and Yamaha XF50.

Engine size in both cases is not far in difference since both are under small engine. By this category, Honda GX35 is more favorably since it will cost less fuel.

In the compression ratio category, Honda GX160 has the higher compression ratio compared to Honda GX35. In this project, compression ratio should be lesser but sufficient enough in order to reduce fuel consumption. Compression ratio is the ratio between the volume of the cylinder and combustion chamber when the piston is at the bottom of its stroke, and the volume of the combustion chamber when the piston is at the top of its stroke

Net horse power of Honda GX160 produces 4.6HP at 3600rpm while the Honda GX35 is considerably much lower.

Honda GX35 is the winner if we talk in term of weight factor of the engine. Honda GX35 only weight about 3.3kg while Yamaha XF50 is estimated to be 5.5kg.

Below is the selection matrix of these two engines.

Criteria	Weight factor
Cost	0.4
Weight	0.3
performance	0.35

Table 4.1.1.2 weight factor

	Honda GX35		Honda GX160	
	score	rating	score	Rating
cost	10	4	7	2.8
weight	7	2.1	4	1.2
performance	2	0.8	9	3.6
Weight property index	6.9		7.6	

Table 4.1.1.3 weight property index

By comparison matrix, the results show that Honda GX35 is the better choice to be implemented on our prototype. Before making the final word, I have consulted with my supervisor on this matter. Agreement has been reach with my fellow teammate in using this engine.

4.1.2 Design of the engine

This is the 3D sketch of the engine of Honda GX160.

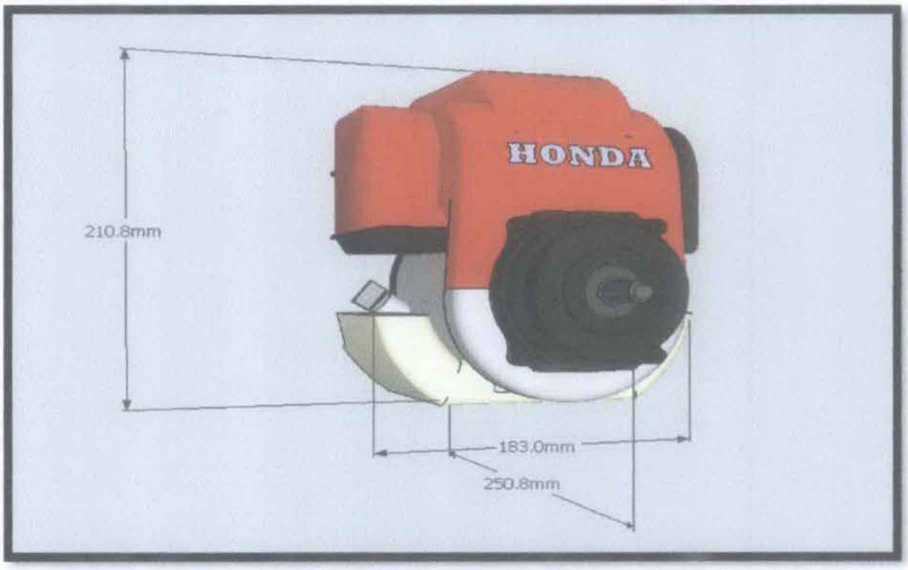


Figure 4.1.2.1 the basic dimension of the engine

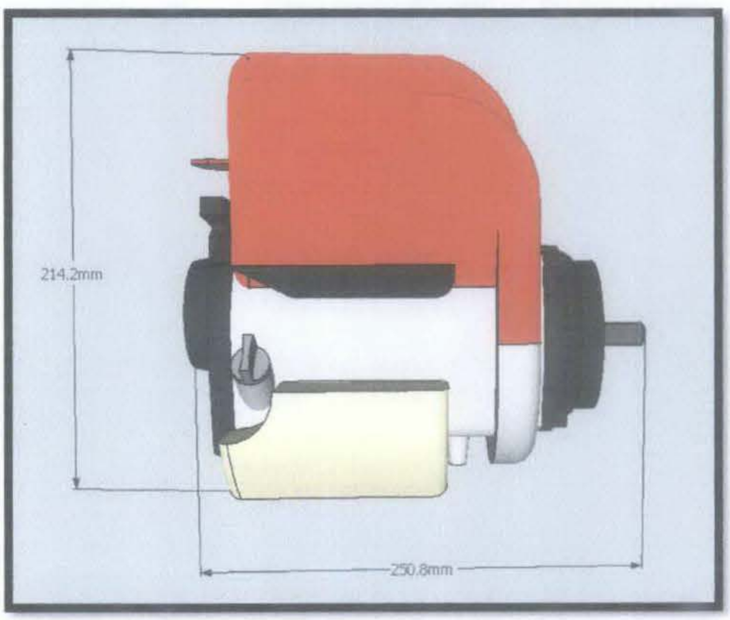


Figure 4.1.2.2 side view of the engine

4.2 Transmission Selection

Transmission	CVT	Rohloff Speedhub	Direct gearing
			

Table 4.2.1 types of transmission

Criteria	Weight factor
Cost	0.5
Weight	0.15
Performance	0.3

Table 4.2.2 weight factor for transmission selection

	CVT		Rohloff derailleur		Direct gearing	
	Score	Rating	Score	Rating	Score	Rating
Cost	7	3.5	3	1.5	7	3.5
Weight	7	1.05	7	1.05	8	1.2
Performance	8	2.4	9	2.7	5	1.5
Weight property index	6.95		5.25		6.2	

Table 4.2.3 weight property index of transmission selection

. As far as advantages are concerned, CVTs provide an unlimited gear ratios and improved performance. The infinite ratios help in maintaining a steady cruising speed. It also cuts down the fuel emissions and thus improves fuel economy. Due to its ability to make changes in the ratio continuously without any steps in between, a CVT can work to keep the engine in its optimum power range, thereby, increasing gas mileage and fuel efficiency. CVT also provides quicker acceleration than a conventional automatic.

4.3 Gear ratio calculation

From the power limited acceleration theory, the tractive effort is given by:

$$F_x = \frac{T_e N_{tf} \eta_{tf}}{r} - \{(I_e + I_t)N_{tf}^{\,2} + I_d N_f^{\,2} + I_w\}\frac{a_x}{r^2}$$

While the acting force to the vehicle is noted by this formula:

$$Ma_x = \frac{W}{g} a_x = F_x - R_x - D_A - R_{hx} - W \sin \emptyset$$

Combine these two equation to get the desired numerical ratio of the transmission will get:

$$N_f = \sqrt{[ma_x + R_x + D_A + W \sin \theta]\frac{r^2}{a_x} - \frac{T_e}{r} + (I_e + I_t) - I_w}$$

Where:

N_f= gear ratio of the transmission

m = the total mass (vehicle+ driver)

a_x= vehicle acceleration

R_x= rolling resistance, $C_r. W$

D_A= aerodynamic force, $\frac{1}{2} C_D \rho A V^2$

θ = road angle

r = tire radius

T_e= engine torque

I_e, I_t, I_w= rotational inertia of engine, transmission and wheel respectivel

The gear ratio is then calculated with estimated velocity, acceleration, road gradient, and time of travel. Below are the calculation that are made through excel.

		g(m/s2)	W(N)	m(kg)	Ie(kg.m2)	It1(kg.m2)	It2(kg.m2)	Iw(kg.m2)	Cd	air density (kg/m3)	frontal area (m2)	tire radius (m)	Te(kg.m)
		9.81	1177.2	120	0.07344014	0.146880279	0.05649242	0.271163592	0.2	1.23	1	0.6604	1.05
Da(N)	ax(m/s2)	v(m/s)	theta	t(s)	v(km/hr)				Nf		distance (m)		
0.96432	0.56	2.8	0	5	10.08				7.2361873		7		
2.16972	0.42	4.2	0	10	15.12				7.3600295		21		
4.72812	0.413333	6.2	0	15	22.32				7.5449044		46.5		
6.37632	0.36	7.2	0	20	25.92				7.7359829		72		
8.27052	0.328	8.2	0	25	29.52				7.9534167		102.5		
10.41072	0.306667	9.2	0	30	33.12				8.196001		138		
12.3	0.285714	10	0	35	36				8.4419691		175		
14.883	0.275	11	0	40	39.6				8.7272443		220		
24.108	0.311111	14	0	45	50.4				9.2811857		315		

Table 4.3.1: gear ratio calculation for initial acceleration on flat road.

Calculating for climbing uphill condition, noting that the road gradient is 10° at maximum (worst condition at sepang circuit) and the result are as shown below in excel.

g(m/s2)	W(N)	m(kg)	Ie(kg.m2)	It1(kg.m2)	It2(kg.m2)	Iw(kg.m2)	Cd	air density (kg/m3)	frontal area (m2)	tire radius (m)	Te(kg.m)
9.81	1177.2	120	0.07344014	0.146880279	0.056492415	0.271163592	0.2	1.23	1	0.6604	1.05

Da(N)	ax(m/s2)	v(m/s)	theta	t(s)	v(km/hr)	Nf	distance (m)
4.428	1.2	6	0.174533	5	21.6	11.27056702	15
6.027	1.4	7	0.174533	5	25.2	10.79904441	17.5
7.872	1.6	8	0.174533	5	28.8	10.4346382	20
9.963	1.8	9	0.174533	5	32.4	10.1451012	22.5
12.3	2	10	0.174533	5	36	9.910088056	25
14.883	2.2	11	0.174533	5	39.6	9.716086186	27.5

Table 4.3.2: gear ratio calculation for climbing hill condition.

Vehicle velocity is taken at 21.6 km/h before climbing the hill as our strategy to climb with momentum meaning that assisted climbing. <u>Considering both cases for initial acceleration and climbing hill, transmission gear ratio of **10** is feasible.</u>

4.3 Powertrain layout

In designing transmission, engine rotational torque need to be considered. For our past SEM 2010, there has been a major problem with chain that connecting output engine shaft and the transmission. That chain had to endure initial load directly from the engine that leads to its breakage. Due to this factor, belting system is preferred at the first stage of the transmission because of its ability to sustain high rotation speed and torque.

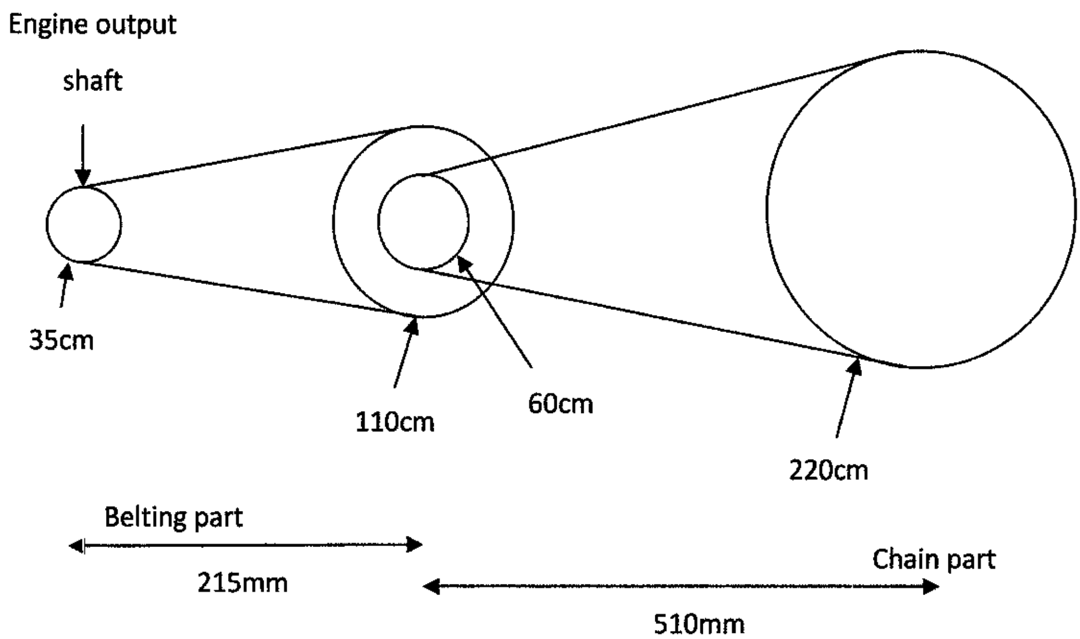


Figure 4.3.1: transmission ratio

With respect to the calculated gear ratio, the above layout has been produced to comply with the result. For this structure, **(110/35)x(220/60) in diameter** will produce a gear ratio of **11.52.**

For this time of period, a draft sketch of the powertrain layout has been done after the selection of the components. Honda GX160 and CVT have been selected to be implemented on our prototype. Below is the sketch drawing of the powertrain layout.

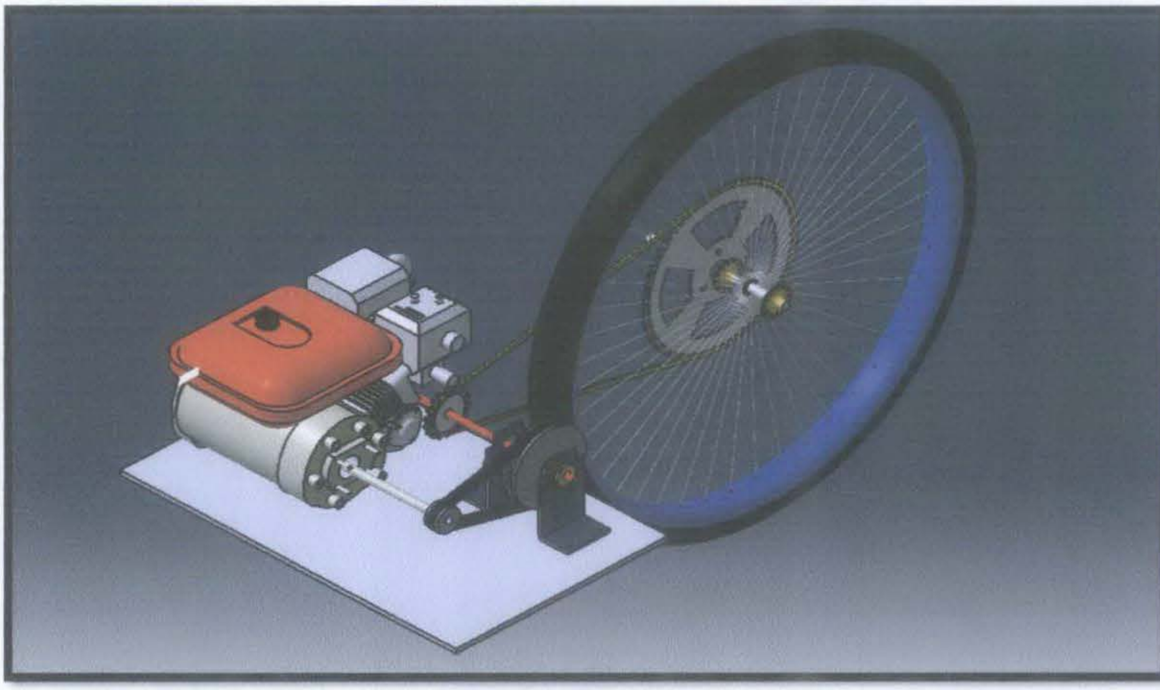


Figure 4.3.1 isometric view of powertrain layout

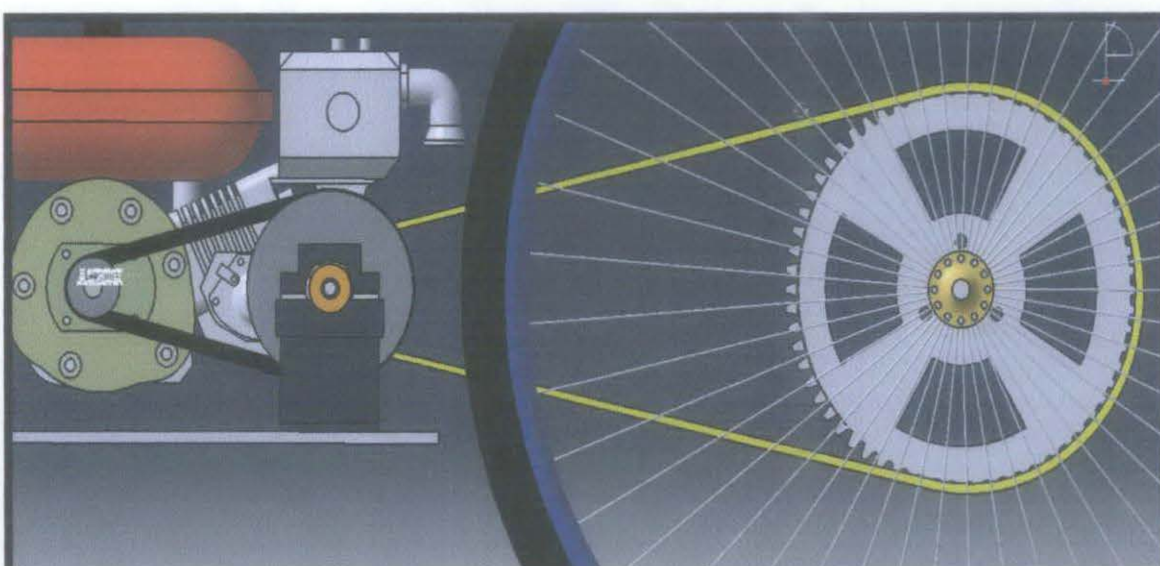


Figure 4.3.2 front view of powertrain layout.

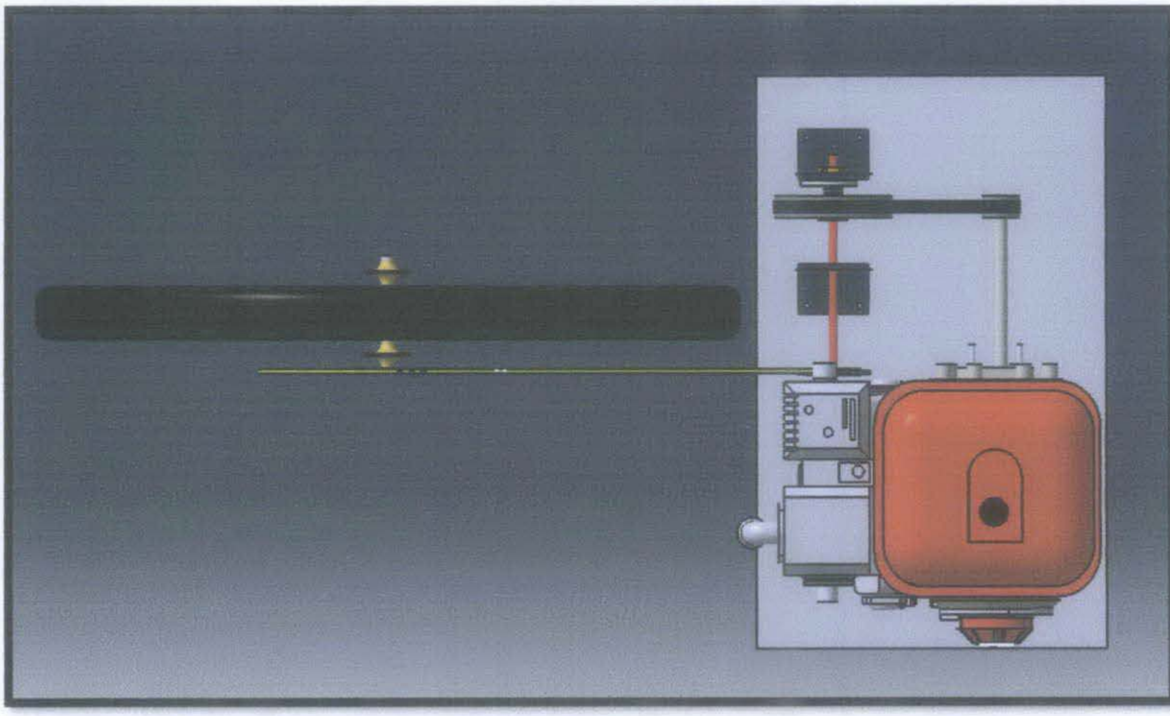


Figure 4.3.3: Top view of powertrain layout.

4.4 Clutch system

Since Shell eco-marathon has a rule that requires the vehicle to be static at idle engine speed, the clutch needed to be design in such way that the vehicle will not move when the engine is initially starts. In the previous batch of SEM 2010, they installed a small centrifugal clutch. There has been a problem where the clutch already engaged the friction plate at the starts of the engine. Due to this problem, the chain had to endure much more force at the starts since the driver had to apply the brake for the car not to move at starts. Thus it will promote to breakage of the chain.

Considering this aspect, our choice of CVT already comes with a bigger clutch as applied to the conventional scooter. Modification is needed to make the spring clutch comply with our engine. The spring needed to be less stiff as the clutch needs to engage at lower engine speed

Figure 4.4 (a) and 4.4(b): spring clutch before and after modification

4.5 PICTURES OF PROTOTYPE

Figure 4.5 (a): front view

Figure 4.5 (b): back view

Figure 4.5 (c): zoomed view

Figure 4.5 (d): fabricated front pulley (alumi

(a)

(b)

(c)

(d)

4.6 DRY RUN AND ANALYSIS

The latter stage of this project is about analysis of the running prototype. After completed with design, fabrication and installation stage, analysis is done to verify the performance of the prototype.

The dry run and analysis objective is

- To check the performance of the prototype whether it match with the theoretical calculation.
- To inspect area of improvisation of the prototype.
- To familiarize the prototype with the Shell Eco-Marathon rules and regulation.

The device that being used to is the DATA LOGGER DL2 RACE TECHNOLOGY

Figure 4.6.1 : DATA LOGGER DL2 RACE TECH

The DL2 can store data from over 30 channels, 100 times every second. Data channels include speeds, accelerations, wheel speeds, shaft speeds, engine speeds, temperatures, pressures, lap times, sector times etc. All the data is stored on a removable compact flash card, which can then be read by a computer. RT software can be used to analyse the data in great detail, or alternatively the data can be exported into standard Matlab or Excel formats for analysis.

4.7 DRY RUN DATA

The complete prototype is tested on a track to evaluate its speed, acceleration and fuel consumption. Besides that, the dry run is to check the flaw of the prototype components to make a proper improvisation.

Figure 4.7.1: dry run at V4 car park

A few runs that have been taken to get a proper value of the fuel consumption and vehicle speed. Below are the pictures of the data that have been acquired.

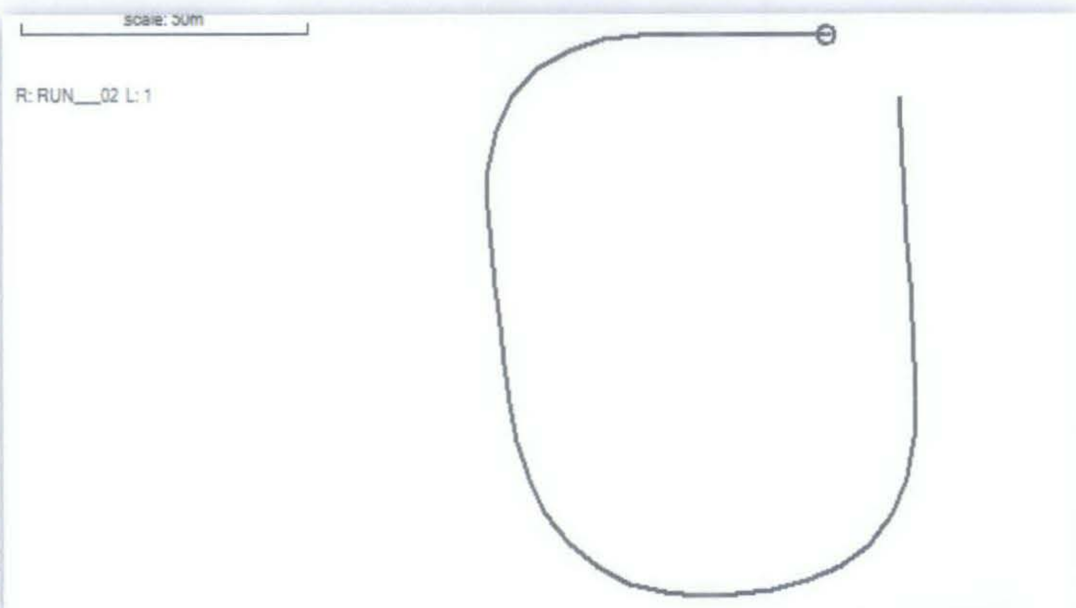


Figure 4.7.2 : track view of the dry run

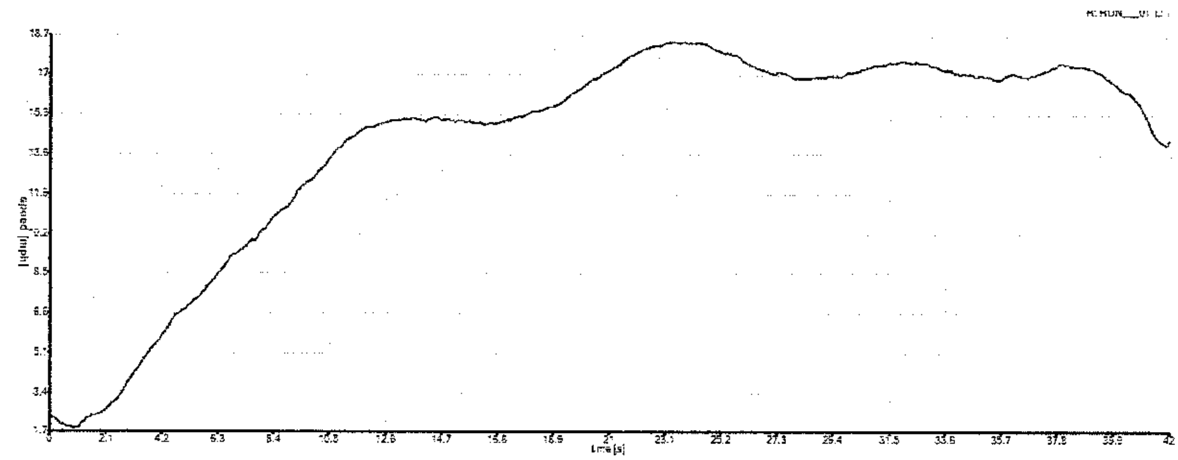


Figure 4.7.3: instantaneous vehicle speed (run 1)

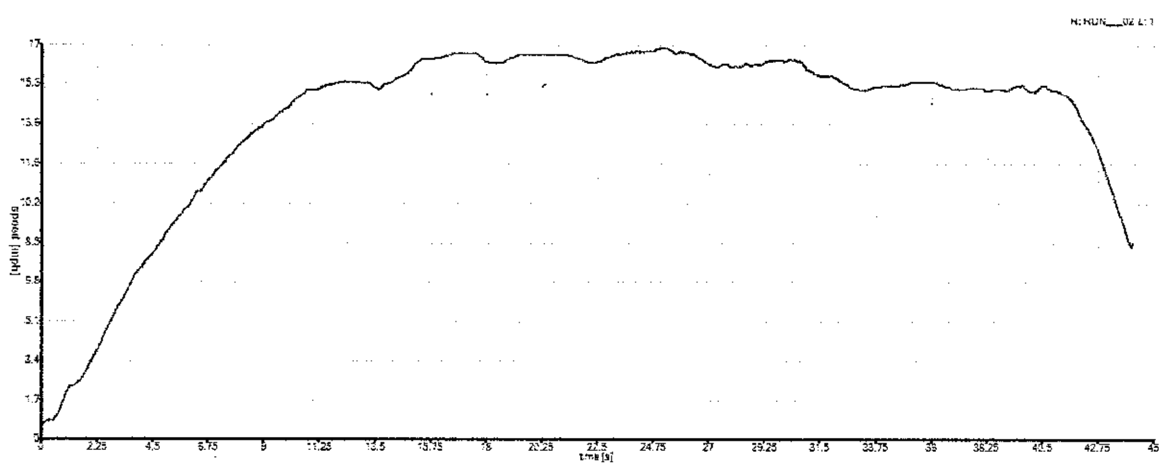


Figure 4.7.4: instantaneous vehicle speed (run 2)

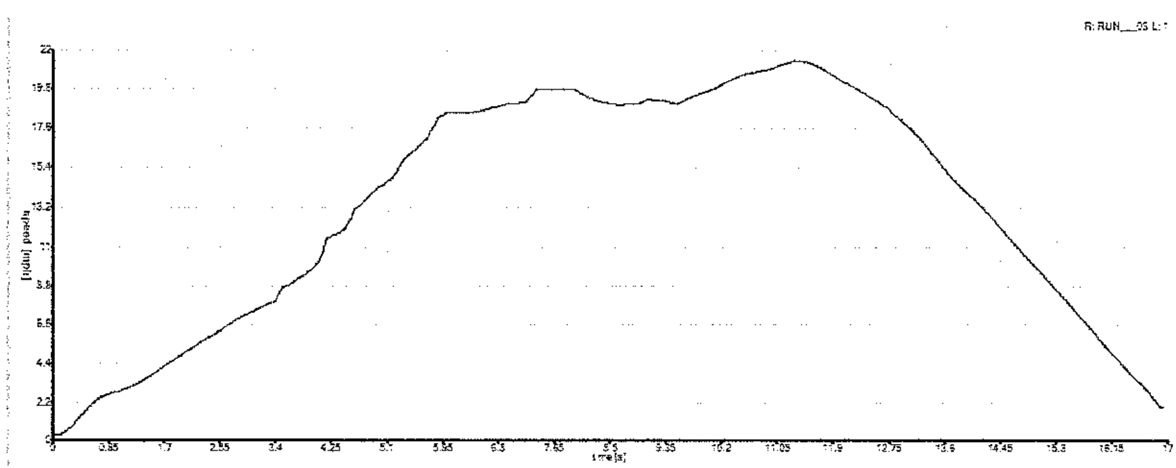


Figure 4.7.5: instantaneous vehicle speed (run 3)

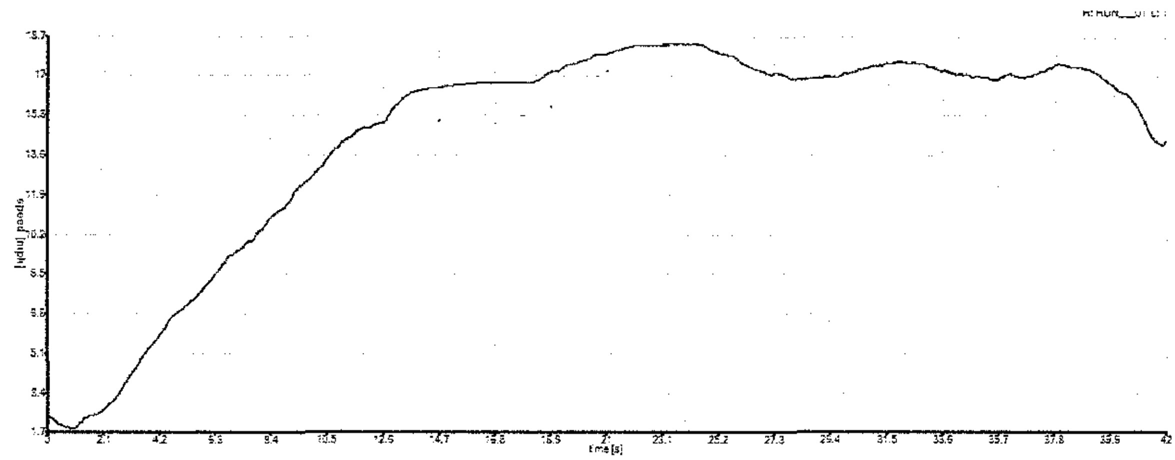


Figure 4.7.6: instantaneous vehicle speed (run 4)

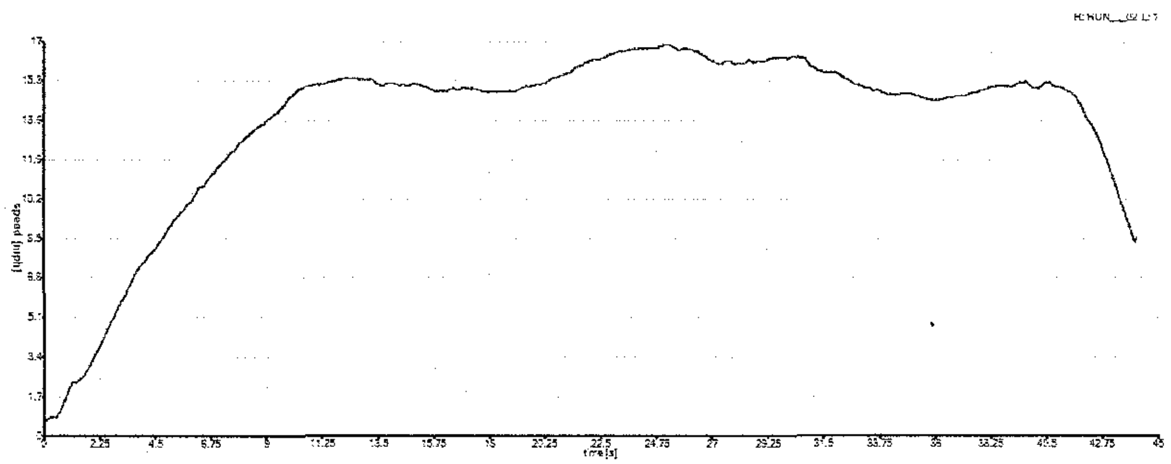


Figure 4.7.7: instantaneous vehicle speed (run 5)

Before the dry run is set, an amount of fuel is filled in the tank. The amount of fuel is measured properly using a measuring tube. Fuel consumption is calculated based on the fuel used after the lap has been completed. The amount of fuel consumption is then divided by the distance covered by the vehicle.

Run	Distance(km)	Fuel consume(liter)	Fuel consumption(km/liter)
1	0.27	0.004	67.5
2	0.28	0.005	56
3	0.26	0.004	65
4	0.27	0.005	54
5	0.30	0.005	60

Table 4.7.1 : dry run analysis data.

All the fuel consumptions data of five runs have been taken into calculation to obtain a better value of overall data.

$$\text{Average Fuel consumption} = \frac{distance(run\ 1+run\ 2+run\ 3+run\ 4+run\ 5)}{fuel\ consume(run\ 1+run\ 2+run\ 3+run\ 4+run\ 5)}$$

$$= \frac{0.27+0.28+0.26+0.27+0.30}{0.004+0.005+0.004+0.005+0.005}$$

$$= \mathbf{60.08}\ \boldsymbol{km/liter}$$ **(Without driving strategy of gliding since the track has no slope)**

Table 4.7.2 comparison with other conventional car

Vehicle type	**Fuel consumption (standard) km/liter**
Utp SHELL eco-Marathon prototype	60
Proton saga BLM 1.3L	13.5
Perodua MYVI 1.3L	15
Perodua VIVA 1.0L	17
Proton waja 1.6L	12

The result calculated from the dry run is being affected by a few factors such as the bearing used, weather condition, tire condition, road condition, engine setting and also driving style.

- Bearing will reduce friction at the rotating part. High speed bearing is very much recommended to increase the mechanical efficiency.
- Weather condition prefer a slightly cool condition because of the engine will to heat up faster and air density is unfavorable at higher temperature for the carburetor.
- Tire is needed to be at optimum condition at certain tire pressure to have good fuel consumption.
- Road condition is one of the major factors where a fine asphalt road will provide better condition compared to a coarse road.
- Fuel consumption differs also by driving style. Different driver will have different time on pedaling the gas.
- Slipping slightly occur at the clutch and belting system.

While to get maximum speed can be reach of the vehicle on flat road without taking the fuel consumption into consideration (no driving strategy).

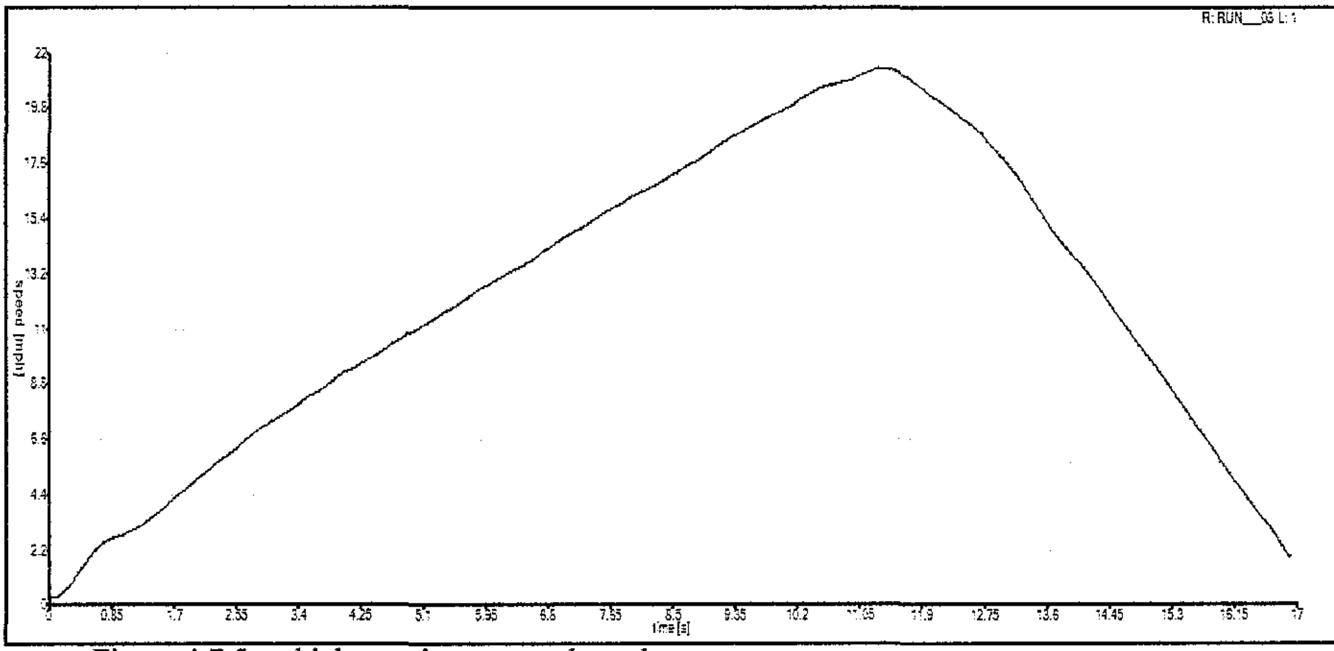


Figure 4.7.5: vehicle maximum speed graph.

The vehicle average maximum speed traveling flat road is **<u>36 km/hour.</u>** The measured speed meets our expectation for a specified time traveled from the calculation. The speed is slightly lower because of a few factors that some of them had been discussed earlier.

CHAPTER 5

CONCLUSION AND FUTURE WORK FOR CONTINUATION

5.1 Conclusion

Table 5.1 show final design selection of Powertain assembly for this semester FYP 2 Shell Eco Marathon UTP car.

Table 5.1 : Final Design Selection of Powertrain assembly

Item	Type
Drive Mechanism	Belt drive and chain drive (primary and secondary chain respectively)
Clutch	Centrifugal clutch
Transmission ratio	11.5/1
Other features	Neutral gear, able to glide, higher reliability on the chain drive.
Speed and acceleration	36km/hour, 3.3km/$hour^2$

Powertrain is one of the systems that contribute significant values of efficiency regarding its power delivery from the engine to the wheels. Proper drive system and gear ratio will reduce the waste of energy. This will promotes to a better efficiency of a system which will reduce the fuel consumption.

Study on the compatibility of the engine and the systems component needed to match perfectly with the needs of efficiency, reliability, flexibility, size, weight and cost constraint. Each of these factors will contribute to the systems efficiency thus relates with the fuel consumption.

As a conclusion, the objectives of this project have been achieved throughout the study and fabrication processes.

Figure below shows the final layout of the prototype.

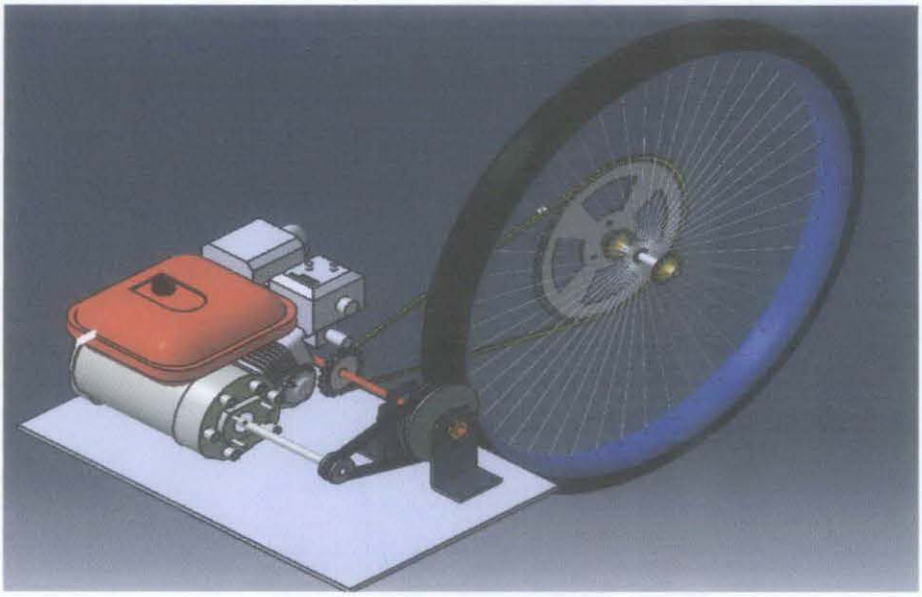


Figure 5.1.1: Final layout of the prototype.

5.2 Recommendations for future work continuation

This project deals with the selection of components, study of gear ratio, fabrication and installation of the prototype. Understanding of dynamic concept of a moving body and characteristic of an engine is highly needed to make this project successful. There are few things that can be upgraded to get a better result in term of project continuation.

- Use high speed bearing at the shaft to reduce friction. Friction will cause mechanical inefficiency and will increase the load to the engine. Friction also will inhibit gliding for the vehicle. The use of grease will also help in term of reducing friction. Also use the plasma arc sparkplug to give more efficient combustion.
- Use wider low resistance tire. Low resistance tire will promotes to a better fuel consumption, but if it is too small it cannot cater the weight of the vehicle and will cause misalignment. Alignment is a very important point that has to be focus in the fabrication and installation stage.
- To reduce slipping at the belt drive, use timing belt or use better shape of pulley. Slipping will introduce power loss.

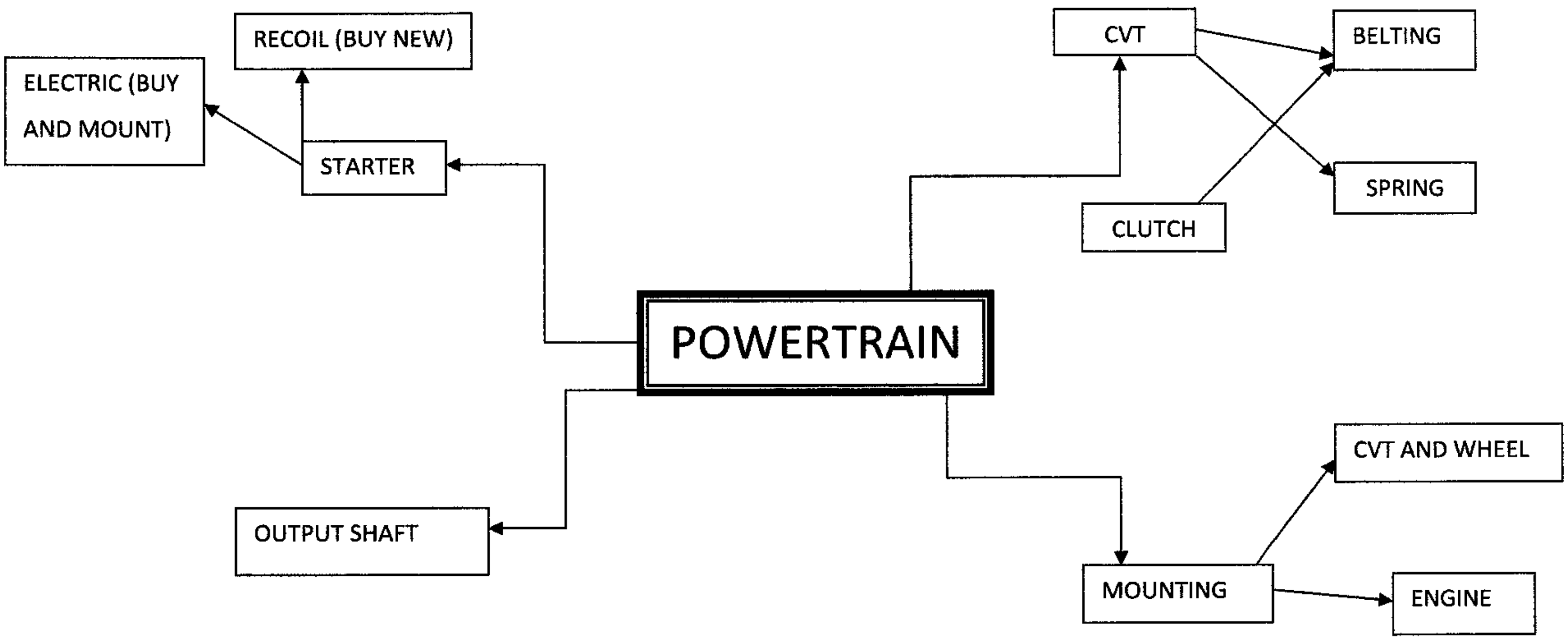
For result analysis, a few recommendations have been identified for future work continuation. To monitor the gear ratio of continuous variable transmission behavior, a camera and a sensor might be usable to predict on how the gear changes throughout the engine rpm variation. For instance, at 2000 rpm, what is the gear ratio that provided by the continuous variable transmission and what is the torque being delivered. On that methodology, one can predict the relationship between the engine rpm, gear ratio and torque.

A few run with data logger but with different rpm will also provide the prediction of the best engine speed that should be run for best fuel consumption.

MILESTONES FOR FYP 2

PROJECT TITLE: ENGINE SELECTION AND DESIGN OF POWERTRAIN FOR SEM 11 FOR OPTIMUM FUEL CONSUMPTION

No	Details/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Fabrication and installation(lab work)															
2	Shell eco marathon race day				☺											
3	Gathering results -prepare the vehicle															
4	Dry run using data logger															
5	Pre-EDX								☺			☺				
6	Submission of draft report												☺			
7	Submission of dissertation													☺		
8	Submission of technical paper													☺		
9	Oral presentation														☺	
10	Submission of project dissertation (hard bound)															☺


POWERTRAIN
STARTER
RECOIL (BUY NEW)
ELECTRIC (BUY AND MOUNT)
OUTPUT SHAFT
CVT
BELTING
SPRING
CLUTCH
MOUNTING
CVT AND WHEEL
ENGINE

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