Upgrading and Optimisation of a Carburetted Engine to Fuel Injection for Best Fuel Consumption

by

Mohd Syahir Bin Mohd Salleh

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

May 2011

SUPERVISOR:

Ir. Dr. Masri Bin Baharom

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Engine and Fuel Consumption Optimization for Competition in Shell Eco Marathon 2010

by

Mohd Syahir Bin Mohd Salleh

A project dissertation submitted to the

Mechanical Engineering Programme

Universiti Teknologi PETRONAS

in partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(MECHANICAL ENGINEERING)

Approved by, ______________________

(Ir. Dr. Masri bin Baharom)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2011

CERTIFICATION OF ORIGINALITY

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

MOHD SYAHIR BIN MOHD SALLEH

ABSTRACT

This Final Year Project (FYP) Report is briefly discusses on the research and study of a small engine working principle and the work step for **Upgrading and Optimisation a Carburetted Engine to Fuel Injection for Best Fuel Consumption**. The main objective of the project is to study about the Electronic Fuel System (EFI) which is a way to reduce the fuel consumption for small engine. This project is putting high expectation on lowest fuel consumption for a prototype, which needs to be run on the farthest distance with one liter of petrol (former target that this project would be used for Shell Eco Marathon Challenge). The challenge for this project is to find the best way to install the EFI system. EFI system is well known by its economical efficiency.

EFI is more economical saving compare to carburetor because it can control the volume of fuel for the engine used, depending on the situation, performance and need of the engine with helped from several sensors. This conversion will greatly improve the engine reliability, consistency and ultimate fuel consumption. The research was undergoing several steps to understand the behavior of the engine, trial runs were done for several engine speeds to know the fuel rate and specific fuel consumption. Alternative fuelling system and parts that needed to be modified had been designed. Lab testing was done for the designed EFI system in order to create the suitable match between the engine and the fuel injection system.

ACKNOWLEDGEMENT

Throughout the progress of my Final Year Project, I would like to acknowledge my family for always being there to provide moral support to me. My family also provided their knowledge on the respected field in order for me to input to the FYP as additional information. The next acknowledgement would be tribute towards my Final Year Project supervisor which is Ir. Dr. Masri bin Baharom. During the progress of the FYP, Ir. Dr. Masri provided lots of feedback that is related to the project as well as provided his valuable experience on the subject. He also introduced to me the aspects needed to do my FYP and the methods which are to be used to analyze the project so that the needed result can be obtained. Besides that, Ir. Dr. Masri always encouraged me to do the best and that the project can be solved by multiple methods and that it is important that we do not stray from the main topic and that it is better to provide more alternatives for the project so that with more choices, chances that a better alternative can be found. The next acknowledgement would be diverted to the various staff in Building 15, 17, 20 and 21 who helps me in fabricating the new engine part for my FYP. Their help and opinion help a lot. They also help me handling the equipment and provide the material for fabrication. My FYP would not be finish in time without help from all of them. I sincerely thank all of the people who contribute in my FYP and it is an honour to work with all of them.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

LIST OF GRAPH

1. INTRODUCTION

1.1 Project Background

Shell Eco Marathon Challenge competition is a platform for the engineering students to design, fabricate and testing the vehicles to reach the farthest distance with one litre of petrol. In conjunction with Shell Eco Marathon, a team is required to build a simple vehicle that will be race in term of having the lowest fuel consumption. A single cylinder four stroke engine is used and some improvement to further reduce its fuel consumption was done by studying the parameter affecting the fuel usage. Engine testing was done to achieve the desired results. Honda GX 35 [1] is the engine for this project. In the beginning of Shell Eco Marathon, Honda GX 35 [1] engine already fitted onto the chassis with original carburettor for its fuelling system. After couple of months, Honda GX 35 was seen cannot afford to give enough torque for CVT transmission. Honda GX 35 was changed to Honda GX 160. In the order to accomplish this project, Honda GX 35 still being carried out the testing and was modified with Electronic Fuel Injection system (EFI) [2]. Several tests were done at lab to get the fuel consumption and fuel rate data in order to differentiate the EFI and carburettor system in term of performance, economical and reliability.

1.2 Problem Statement

Generally, this project was carried out in order to improve the fuel consumption of an engine using Electronic Fuel Injection because this system is better than carburetor. Originally, Honda GX 35 engine made use carburetor for its fuelling system. Other than that, knowledge about EFI is very limited and further study need to be carried out to accomplish this project.

1.3 Objective

The main objectives of this research are:

- To install an EFI system in order to replace carburetor.
- To reduce the fuel consumption of an original engine.
- To study on EFI system and modification needed in order to use the system at Honda GX 35 engine.

The objective for Shell Eco Marathon 2011:

- Improve engine system for optimum fuel consumption
- Use fuel injection system to improve fuel consumption.
- Improve the drive train system to deliver engine RPM to the wheel at cruising speed.
- Improving the body of the prototype in term of weight and durability.
- Reducing the weight of the car by making SEM10 car as a reference

Figure 1.1.1 : Shell Eco Marathon 2011's prototype

1.4 Scope Of Study

The scope of study for this project is divided in two parts which, part one is the FYP 1 and part two is the FYP 2 as below:

- FYP 1

This part was started by investigating how to install a proper EFI system to the Honda GX 35 engine. Besides that, preparation of the tools and component required to mount the EFI system to the engine were done.

- FYP 2

Modification on the engine parameters especially EFI system and carburetor were done and the improvement on fuel consumption for the same engine already been investigated. Besides that, flow rate of the fuel and fuel combustion effiency for both systems were recorded. Modification on intake port was made in order to mount the EFI nozzle at carburetor original location. Next, engine testing was done for each fuelling system and the data had been taken for analysis purpose.

Lastly, a coupler had been designed and the calculated slope of extension was fabricated just to make sure the angle of fuel spray was direct into combustion chamber.

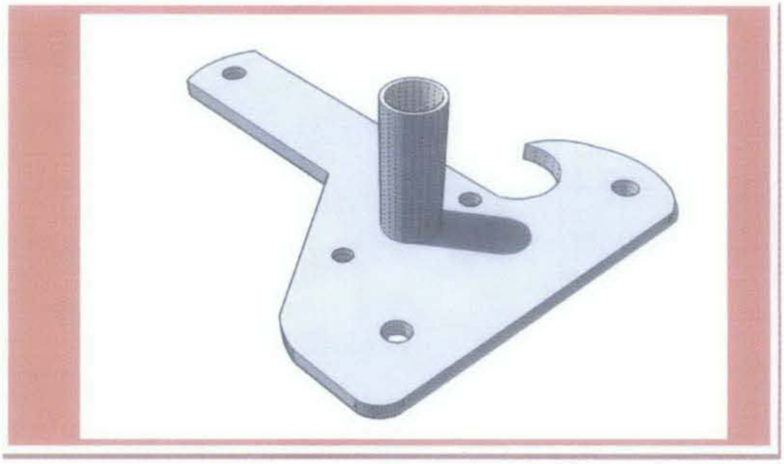


Figure 1.4.1 : ISO view of coupler sketch drawing

Figure 1.4.2 : Slope extension using mild steel for straight fuel spray purpose

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

2.1.1 Basic Theory of Carburetor

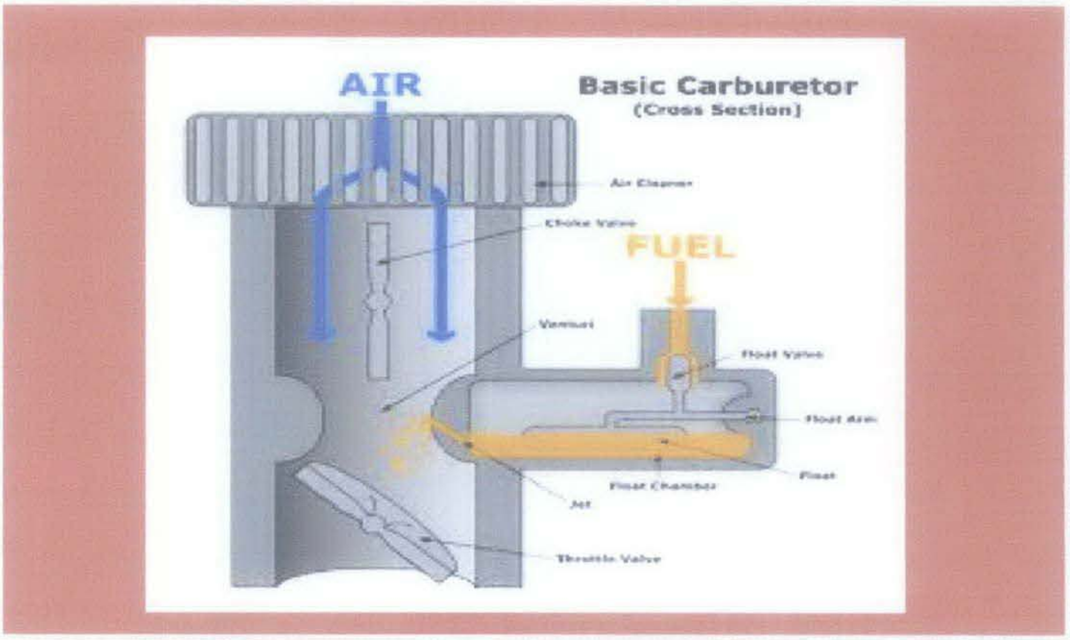


Figure 2.1.1 Carburetor system

Carburetor is a mixing device that supplies the engine with a combustible air-fuel mixture [3]. In the carburetor, there is a restricted space called venturi that gives a path for the air to enter the engine [3]. The air movement produces a partial vacuum in the venturi. Its called venturi vacuum [3]. The resulting pressure differential causes fuel to discharge from the fuel nozzle into the intake air. This process produces the air-fuel mixture for the engine [5]. The goal of a carburetor is to mix just the right amount of gasoline with air so that the engine runs properly. When the throttle valve increase its opening, there is more fuel that being vacuumed to mix with the air and will produce more power when ignited [5]. The disadvantage of this system is it cannot control the quantity of fuel that needed for the engine because it is totally mechanical principle which is suction of air, fuel and vacuum.

2.1.2 Basic Theory of Electronic Fuel Injection System

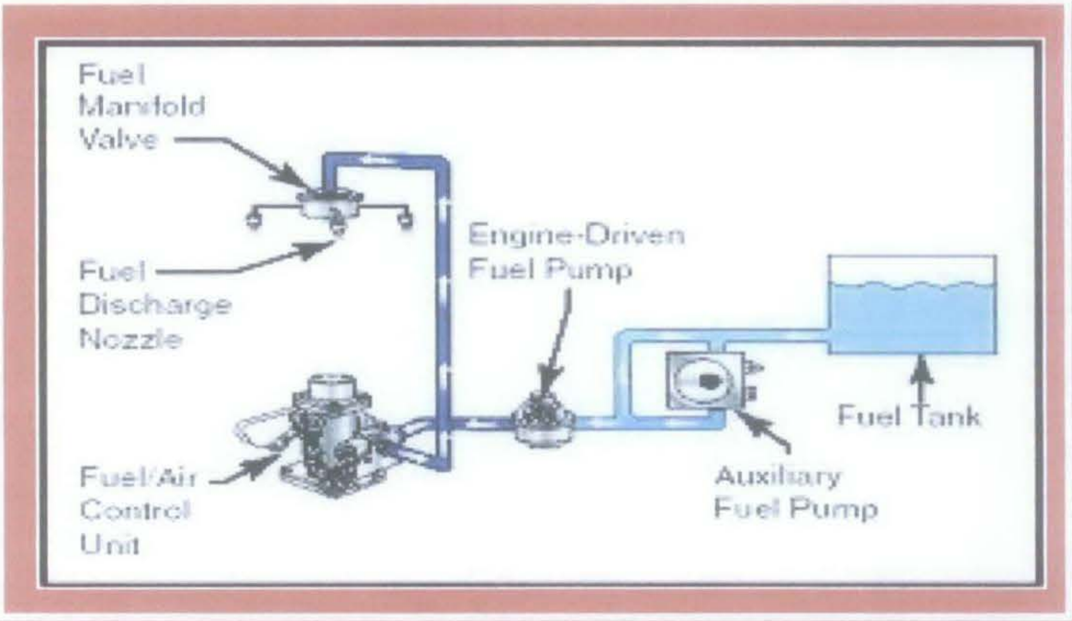


Figure 2.1.2 Electronic Fuel Injection System

In an internal combustion engine, the electronic fuel injection system is that which delivers fuel or a fuel-air mixture to the cylinders by means of pressure from a pump [2]. Process is starting with the fuel has to mix with air, and the resulting mixture is delivered to the cylinder. Computers are used in modern fuel injection systems to regulate the process [4]. The positive effects of fuel injection are that there is more efficient fuel combustion [2], better fuel economy and engine performance and reduced polluting exhaust emissions. Typical EFI components are [4]:

- Injectors - injects the fuel into combustion chamber.
- Fuel Pump – give pressure for fuel to flow.
- Fuel Pressure Regulator – control the pressure at exact value.
- ECM - Engine Control Module; includes a digital computer and circuitry to communicate with sensors and control outputs.
- Wiring Harness.
- Various Sensors such as:
- Crank/Cam Position: Hall effect sensor
- Airflow: MAF sensor, sometimes this is inferred with a MAP sensor
- Exhaust Gas Oxygen: Oxygen sensor

Electronic fuel injection (EFI) system consists of a computer called the Engine Control Unit (ECU), which monitors engine operating parameters via various sensors. The ECU interprets these parameters in order to calculate the appropriate amount of fuel to be injected, among other tasks, and controls engine operation by manipulating fuel and/or air flow as well as other variables [4]. The optimum amount of injected fuel depends on conditions such as engine and ambient temperatures, engine speed and workload, and exhaust gas composition [4].

2.1.3 Honda GX 35

For this project, engine that being chosen was Honda GX35 [1], a four stroke engine, 35 cc and overhead cam single cylinder. The details for the engine [1] are:

- Engine type : Air cooled 4-stroke single-cylinder OHC petrol engine
- Bore x stroke : 39 x 30 mm
- Displacement : 35.8 cm3
- Compression ratio : 8.0
- 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 consumption 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

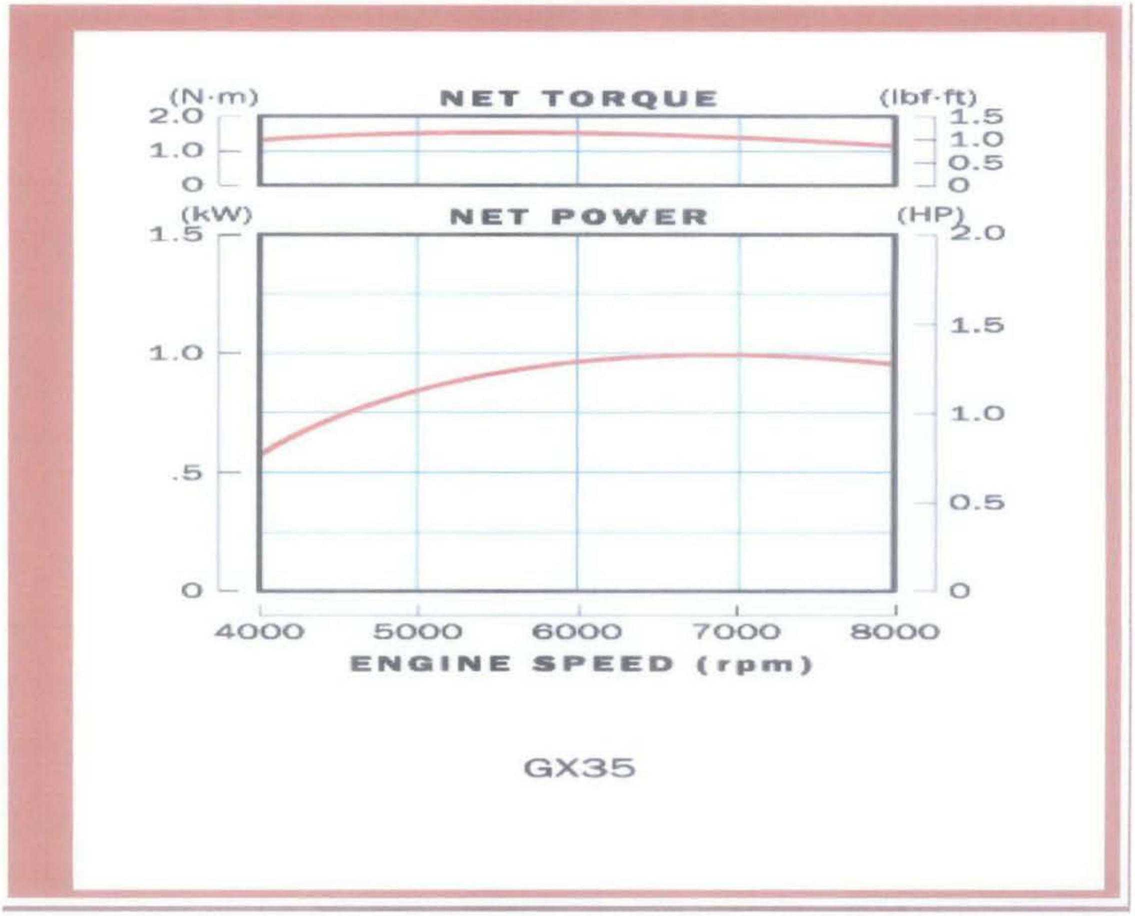


Figure 2.1.3.1 : Torque and Power of the engine

Figure 2.1.3.2: Honda GX35 on the prototype

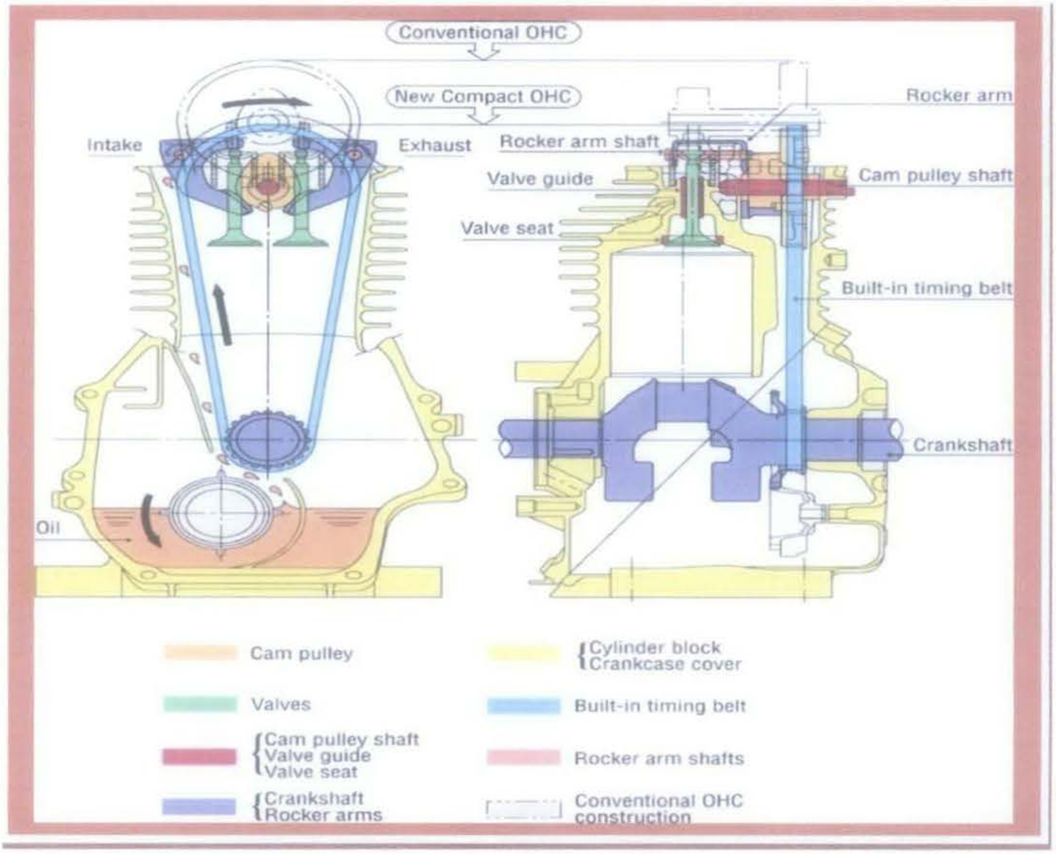


Figure 2.1.3.3 : Cross section of Honda GX 35

With the specification above, this engine was used for a prototype with three wheels. The needed torque in order to run the prototype is approximately 1.5 Nm. Because of this project is highly target for low fuel consumption and not for high speed, the prototype approximately will travel about 30 km/h generally. The power estimation is about 1.0 HP. With this engine, it can provides the power and torque needed for this project.

Figure 2.1.3.4: Honda GX35 for testing

Figure 2.1.3.5: Honda GX35 with stock carburetor

Figure 2.1.3.6: Honda GX35 with new EFI system

2.1.4 FC Design Fi-M Digital Fuel Injection

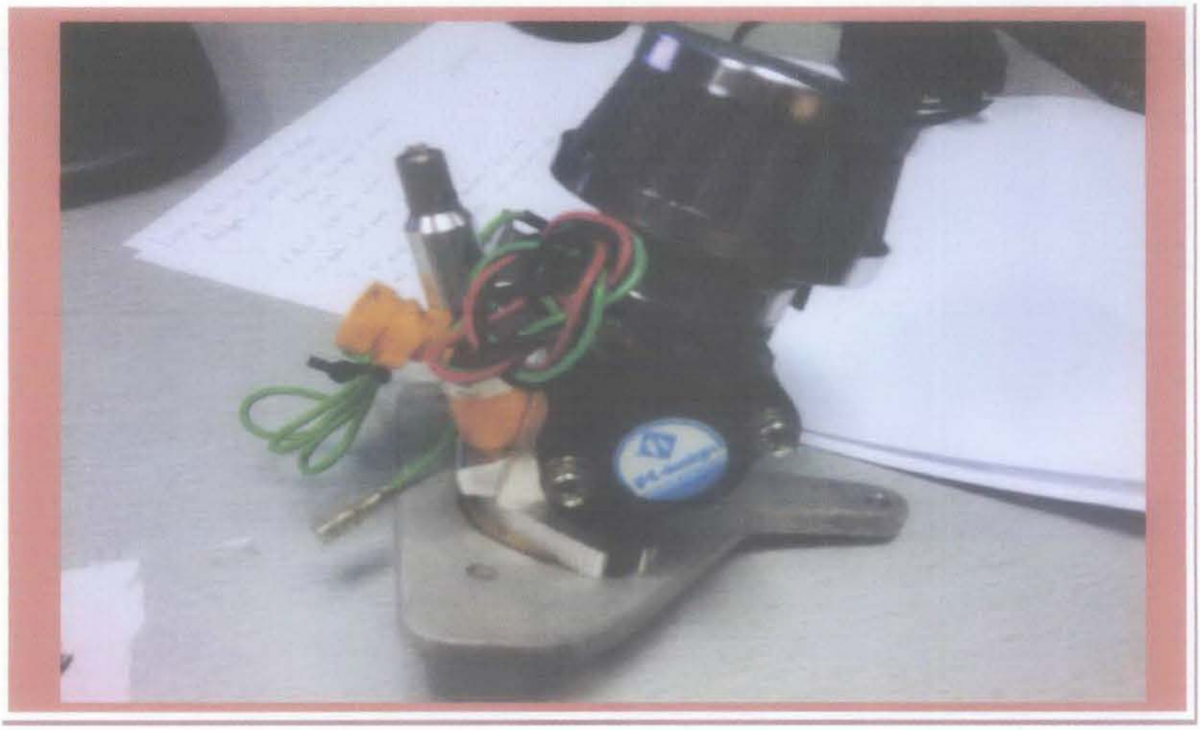


Figure 2.1.4.1: FC Design Fi-M Digital Fuel Injection System

The chosen EFI system was FC Design Fi-M Digital Fuel Injection System [7]. The details for this EFI system [7] are:

Feature of Fi-M [7].

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

Additional feature of Fi-M digital [7].

- The controller can display the following engine / vehicle data in "Meter function".
  - 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.]
  - Engine hour meter.[h.m.s]
  - Supplied voltage. [Volts]
  - Temperature. [degree Celsius].

Firstly, this device has an injection control. Using Fi-M digital controller, we can control the fuel injection time either on idle injection time (ID) or wide open throttle injection time (WOT). ID function is suitable for idling condition where speed of the engine is low. Next, we can control the fuel injector opening time by set the timing and cycle of the current pulse that being supplied to the fuel injector. For example, we decrease the period of cycle to shorten the opening period of injector. In other word, we do not have to adjust the fuelling pressure using fuel pressure regulator.

Then, using this device, we can inject fuel before the engine started. It helps in order to start the engine easily. Lastly this device is from Japan and the production is just for research purpose that suitable for small engine.

2.1.5 Fuel Pressure system.

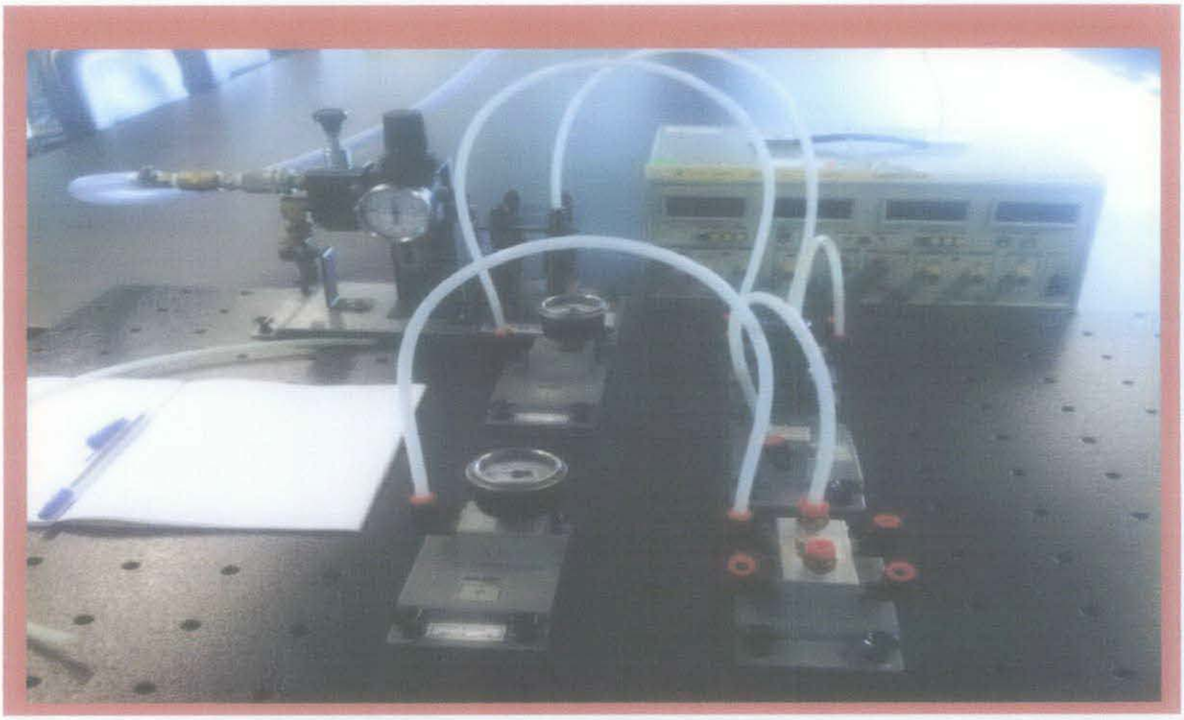


Figure 2.1.5.1 : Fuel Pressure system being test at Mechatronic Lab

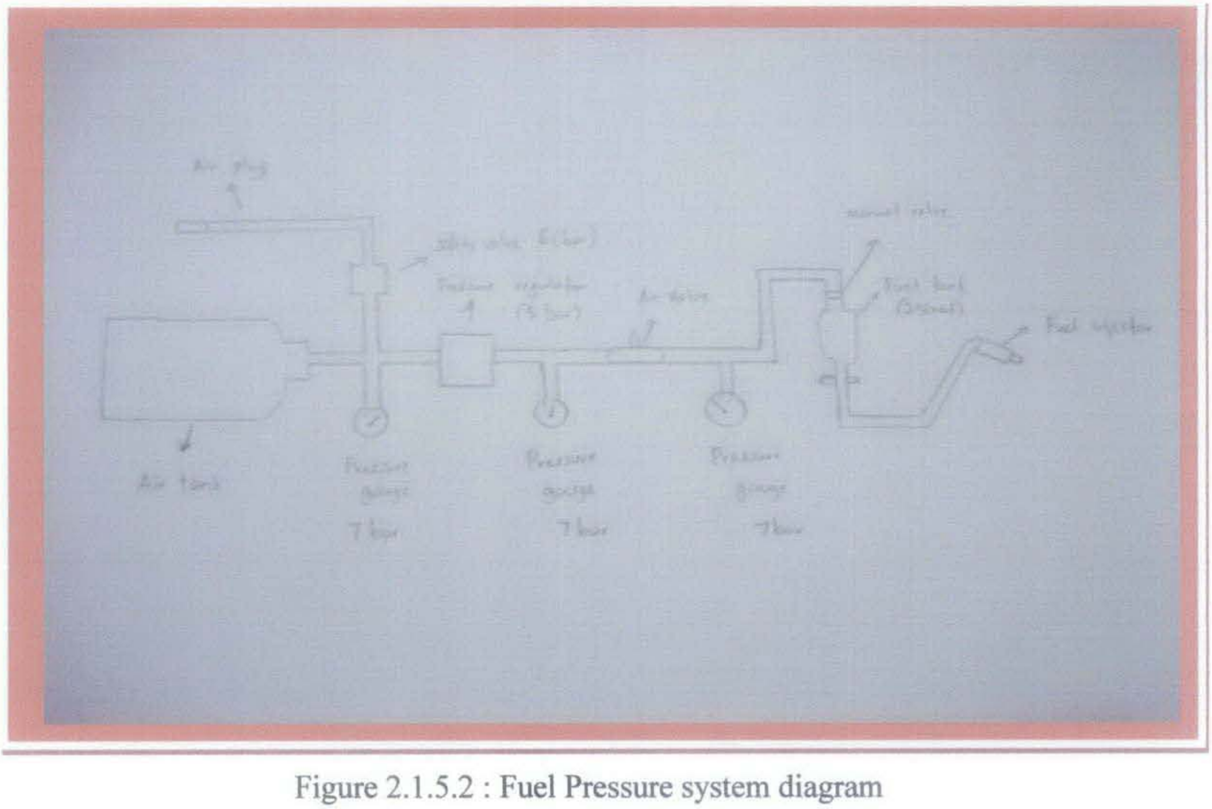


Figure 2.1.5.2 : Fuel Pressure system diagram

In Shell Eco Marathon rules and regulations, they have stated that there must be no outside pump used at the vehicle. EFI system needs pressure system that could give sufficient pressure to the nozzle. Therefore, fuel pressure system was used and this system was using air to give the pressure.

Fuel pressure system needed in order to give sufficient pressure for EFI fuel injector to inject the fuel into the combustion chamber. For fuel injector, they need 2-2.5 bar of pressure to spray the fuel. Higher of pressure was better because the fuel will change from liquid to gas (better atomization) before enter the combustion chamber and it helps to give a complete combustion and better performance for the engine. There are several devices had to be prepared in order to build stand alone fuel pressure system, they are:

a. Fuel tank
b. Air tank
c. Pressure gauge
d. Pressure regulator
e. 'T' joint
f. Tubing

2.1.6 Examples of Engine From Other University

2.1.6.1 Institute Technology Sepuluh, Surabaya

An example of a vehicle from Institute Technology Sepuluh, Surabaya has been studied. The name of the vehicle was Sapu Angin 1 [8]. The details of the vehicle are:

Body: Monocoque fiberglass
Engine: 35 CC, 4 stroke OHC (Internal Combustion)
Fuel System: EFI
Fuel: Gasoline

Figure 2.1.6.1 : Sapu Angin 1, ITS

Sapu Angin 1 was used the same engine like us, which was Honda GX 35. This engine was changed from the carburetor to EFI System. Type of EFI system that they used was not being tell(confidential). Overall, they successfully convert the carburetor to EFI system with fine tuned.

2.1.6.2 Universitas Indonesia 2010 SEM

Keris designed in semi-monochoke method, where its body and frame is joined but not in one piece. There is Keris' specification:[9]

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 : Bicycle transmission

KERIS

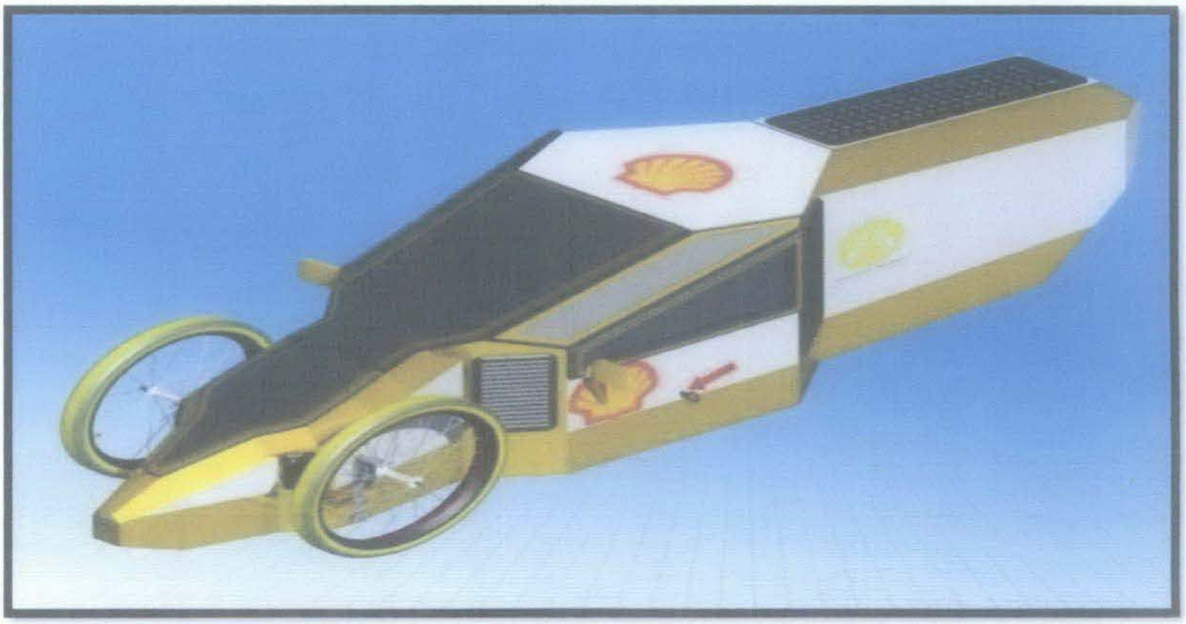


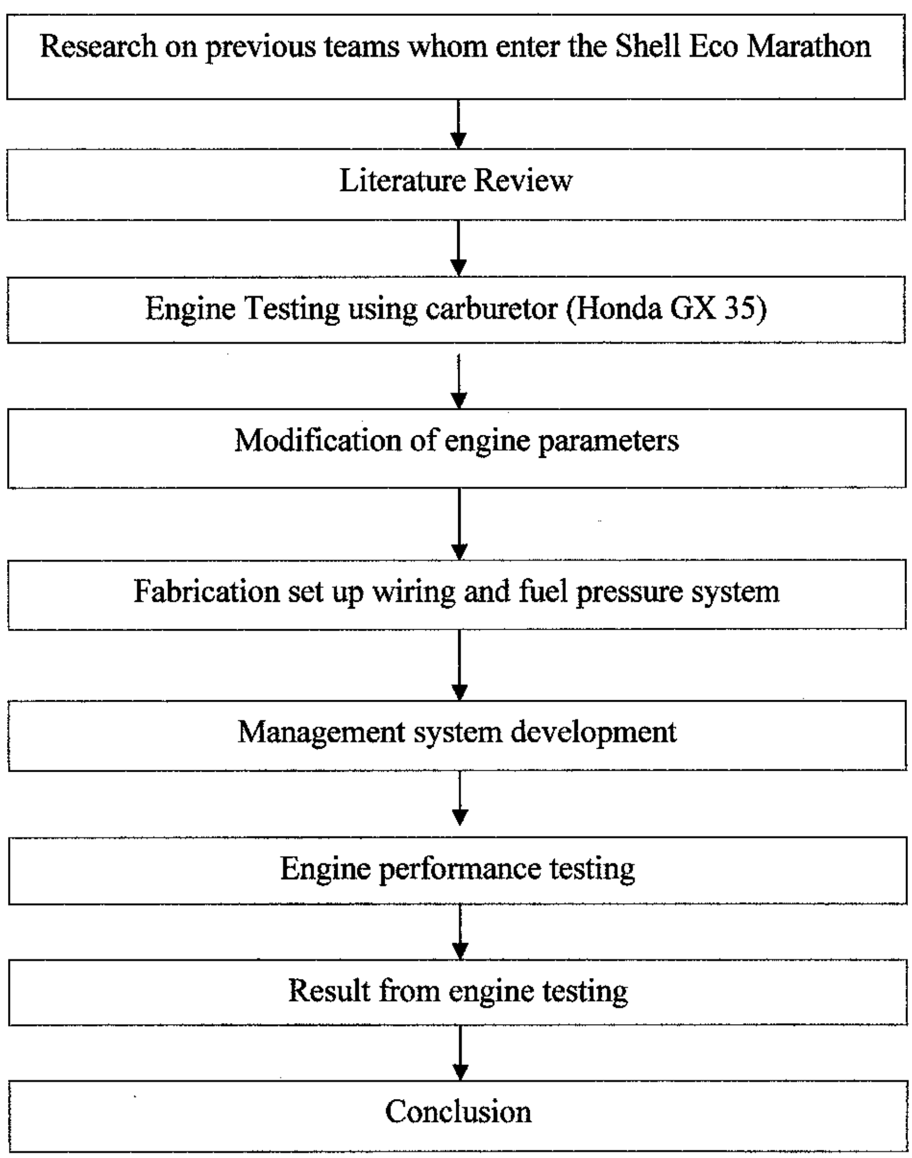
Figure 2.1.6.2 :KERIS's 3D model.

CHAPTER 3

METHODOLOGY

3.1 PROJECT IDENTIFICATION

Engine Testing Process



3.1.1 Research on previous teams whom enter the Shell Eco Marathon

The information about the Shell Eco Marathon is gathered from available resources such as internet, books, or journal. The objective of this phase is to obtain some meaningful knowledge about the project and get some general idea to have a better insight about the project.

3.1.2 Literature Review

Some research is done in this phase to get some idea about the project. Much information is gathered in order to get clearer view about this project. Some of the information is not related to the project. Hence, at this stage, the information will be filtered and only useful information will be taken into consideration. The crucial parts are the basic theory of every fuelling system. Good understanding in every system is required in order to complete this project.

3.1.3 Engine Testing using carburetor (Honda GX 35)

Honda GX 35 was tested with its original carburetor system. The target for this phase is to get the bench mark data. In this process, the data that had been documented was engine fuel rate for certain engine speeds. After the data is gathered, the next step is the conversion of EFI system.

3.1.4 Modification of engine parameters

Carburetor system will be swap with the EFI system. In this phase, a coupler had been designed in order to mount the fuel injector onto the intake port. Slope of extension was calculated to make sure the injector will spray the fuel straight directly into the combustion chamber. Slope of extension was welded together with the coupler.

3.1.5 Fabrication, set up wiring and fuel pressure system

Fabrication of the coupler was done in this phase. Next, wiring system to power the EFI has been set up. A 12V, 5 Amp battery is used in this process. Then, fuel pressure system is prepared in order to supply the pressure to the fuel injector. Pressure of air given to the injector was approximately about 2-2.5 bar.

3.1.6 Management system development

ECU for EFI system had been set up. The value for every engine system parameter was inserted into ECU data before it can function well. It was including fuel volume over minute (fuel flow rate), engine speed and idle or WOT function.

3.1.7 Engine performance testing

Honda GX 35 engine with EFI system was tested again. The target for this phase is to get the data for the engine that run with EFI. In this process, the data that had been documented was the fuel flow rate for certain speeds, same as Honda GX 35 with carburetor.

3.1.8 Result from engine testing

The results from both EFI and carburetor are gathered together. Some calculations were done to compare the EFI and carburetor results.

3.1.9 Conclusion

Conclusion is done in this phase in order to get the differences between EFI and carburetor system.

Tests that that being conducted for this project:

a. *Carburetor engine testing.*

   To know the performance of the original engine that used carburetor system in terms of engine speed and fuel flow rate. This testing was conducted and gives some reading to be analyzed.

b. *EFI engine testing.*

   Study the improvement on engine performance like fuel consumption after EFI had been assembled to the engine. This testing will provide the practical data after the engine has been running at several engine speeds.

There were also mechanical manufacturing processes that involved in this project including:

Mechanical processes	Part that involved
Milling	Slope extension at EFI system using Mild Steel
Lathe	Coupler from the engine to electric starter
Welding	Joining the slope extension to the coupler
Drilling	Make hole into the chassis to mount the engine.

Figure 3.1.1 : Table of mechanical processes and part that involved

3.2 PROCEDURES

3.2.2 Engine testing procedure

The purpose of this procedure is to make sure the result that we get is **standardized**, correct and can be compared to each other.

To start the engine testing:

1. Mount the photoelectric sensor at dummy plate to read the engine speed.

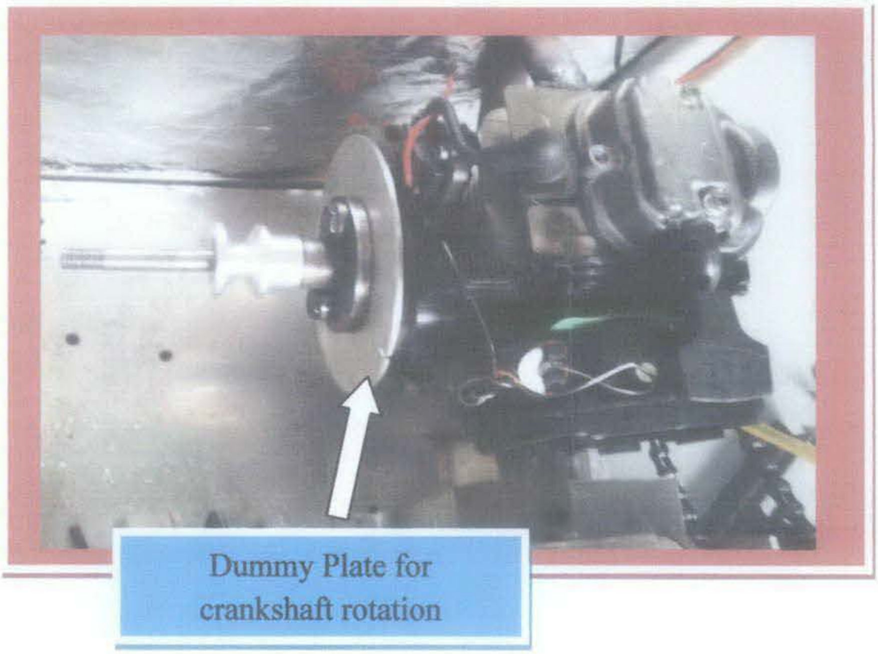


Figure 3.2.1: Dummy plate at crank shaft

2. Switch On the ECU box. (Engine speed reading for carburetor and control fuel spray rate using nozzle for EFI system)
3. Fill a tube (burette) with fuel at fix volume and engage the tubing into carburetor or EFI.
4. Set up the surrounding like the exhaust, engine oil at the fix level.

   a) Carburetor

      1. Put the choke at max level.
      2. Open the throttle at half open.
      3. Start the engine.
      4. Run the engine at 1500 rpm
      5. Measure the time until the engine run out of fuel.
      6. Repeat step 1 until 6 (except 4) at several speed : (1500rpm-6000rpm)

b) EFI system

1. Engage the burette at EFI nozzle.
2. Set the pressure gauge of fuel system at 2.0 bar
3. Start the engine.
4. Run the engine at 1500 rpm
5. Measure the time until the engine run out of fuel.
6. Repeat step 1 until 6 (except 4) at several speed : (1500rpm-6000rpm)

Figure 3.2.2: Engine speed reading at ECU

Figure 3.2.3: Injection number and volume of fuel reading at ECU

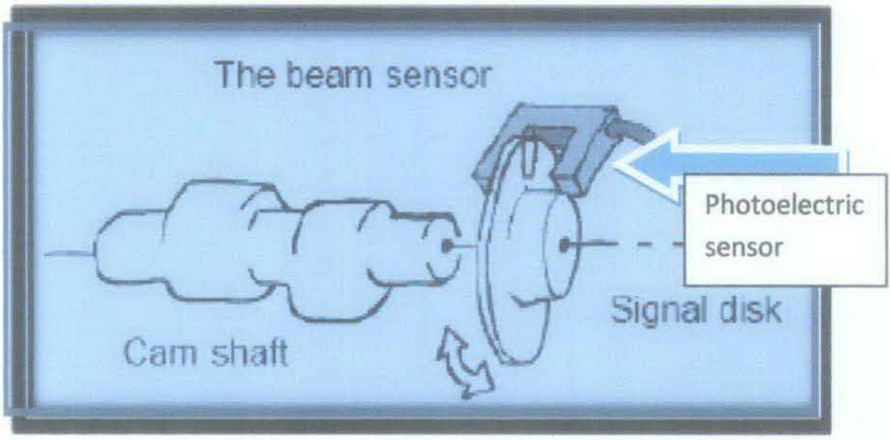


Figure 3.2.4 :EFI system, dummy plate and photoelectric sensor

Figure 3.2.5: Fuelling rate of injector reading at ECU

MILESTONES FOR FYP 2

PROJECT TITLE : Upgrading and Optimisation of a Carburetted Engine to Fuel Injection for Best Fuel Consumption

MOHD SYAHIR BIN MOHD SALLEH

10251

MECHANICAL ENGINEERING

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															
4	Submission of progress report															
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)															

MILESTONES FOR FYP 1

PROJECT TITLE: Upgrading and Optimisation of a Carburetted Engine to Fuel Injection for Best Fuel Consumption

MOHD SYAHIR BIN MOHD SALLEH

10251

MECHANICAL ENGINEERING

NO	DETAIL	WEEK														
		1	2	3	4	5	6	MID-SEMESTER BREAK	7	8	9	10	11	12	13	14
1	Primary Research Work															
2	Submission of Preliminary Report				●											
3	Project work (measurement and research on the previous engine part: fuel injection system)															
4	Research about the coupler (for EFI system)															
5	Research on other team.															
6	Obtained the information from previous SEM member, technician and lecturer.															
7	Make the project ready for fabrication with complete data.															
8	Submission of Progress Report									●						
9	Seminar (compulsory)									●						
10	Submission of Interim Report Final Draft															●
11	Oral Presentation(study week)															

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1.1 Engine Running Data (Carburetor vs EFI system)

Engine running data for carburetor and EFI system were calculated in order to get the differences for both systems in term of performance, reliability and consistency. The data which were calculated including fuel flow rate, specific fuel consumption, air fuel mixture ratio and fuel combustion efficiency as below:

4.1.2 Fuel flow Rate

Fuel flow rate is the ratio of fuel volume over the time taken for the fuel to empty. This test was done by fuelling a tube (known dimension) at specific volume and run the engine. The time taken was counted down from the fuel is full in tube until it is totally empty. The **lowest value of fuel rate** means it is **more economical** because it uses **lower volume of fuel for certain period of time to empty**. This test was done at several engine speeds. Both fuelling systems (EFI and carburetor) were run on this same test. In this below calculation, the data for 4000 rpm of engine speed was used.

Specification of the tube (burette):

Diameter : 0.9 cm

Length : 10 cm

Volume : $\pi r^2 L$

$= \pi (0.9/2)^2 L$

$= 3.142 \times (0.45)^2 \times 10$

$= 6.363 \text{ cm}^3$

Carburetor

Test Run Number	Time (seconds)
1	80
2	82
3	81
4	82
5	80

Figure 4.1.2.1 : Table of Test Run number and time for carburetor

Engine speed: 4000 rpm

Power : 0.52kW

Torque: 1.2 Nm

Average time : 81 seconds.

Fuel Rate : 6.363cm^3 $\div$ 81 sec

$$= \left(4.713 \times 10^{-8} \frac{cm^3}{min}\right) \times \frac{1m^3}{(100^3)cm^3} \times \frac{1\,min}{60\,sec}$$

$$= 7.855\, x\, 10^{-8} \frac{m^3}{sec}$$

*Gasoline Density = $719.7 \frac{kg}{m^3}$

$$= 7.855\, x\, 10^{-8} \frac{m^3}{sec} \text{ x } 719.7 \frac{kg}{m^3}$$

$$=5.653 \times 10^{-5} \frac{kg}{sec} \times \frac{1000g}{1kg}$$

$$=0.05653 \frac{g}{sec}$$ #

EFI system

Test Run Number	Time (seconds)
1	85
2	87
3	83
4	86
5	84

Figure 4.1.2.2 : Table of Test Run number and time for EFI system

Engine speed: 4000 rpm

Power : 0.52kW

Torque: 1.2 Nm

Average time : 85 seconds.

Fuel Rate : $6.363cm^3 \div 85\,sec$

$$= \left(4.477 \times 10^{-8} \frac{cm^3}{min}\right) \times \frac{1m^3}{(100^3)cm^3} \times \frac{1\,min}{60\,sec}$$

$$= 7.46\,x\,10^{-8} \frac{m^3}{sec}$$

$*$Gasoline Density $= 719.7 \frac{kg}{m^3}$

$$= 7.46\,x\,10^{-8} \frac{m^3}{sec} \text{ x } 719.7 \frac{kg}{m^3}$$

$$=5.37 \times 10^{-5} \frac{kg}{sec} \times \frac{1000g}{1kg}$$

$$=0.0537 \frac{g}{sec} \#$$

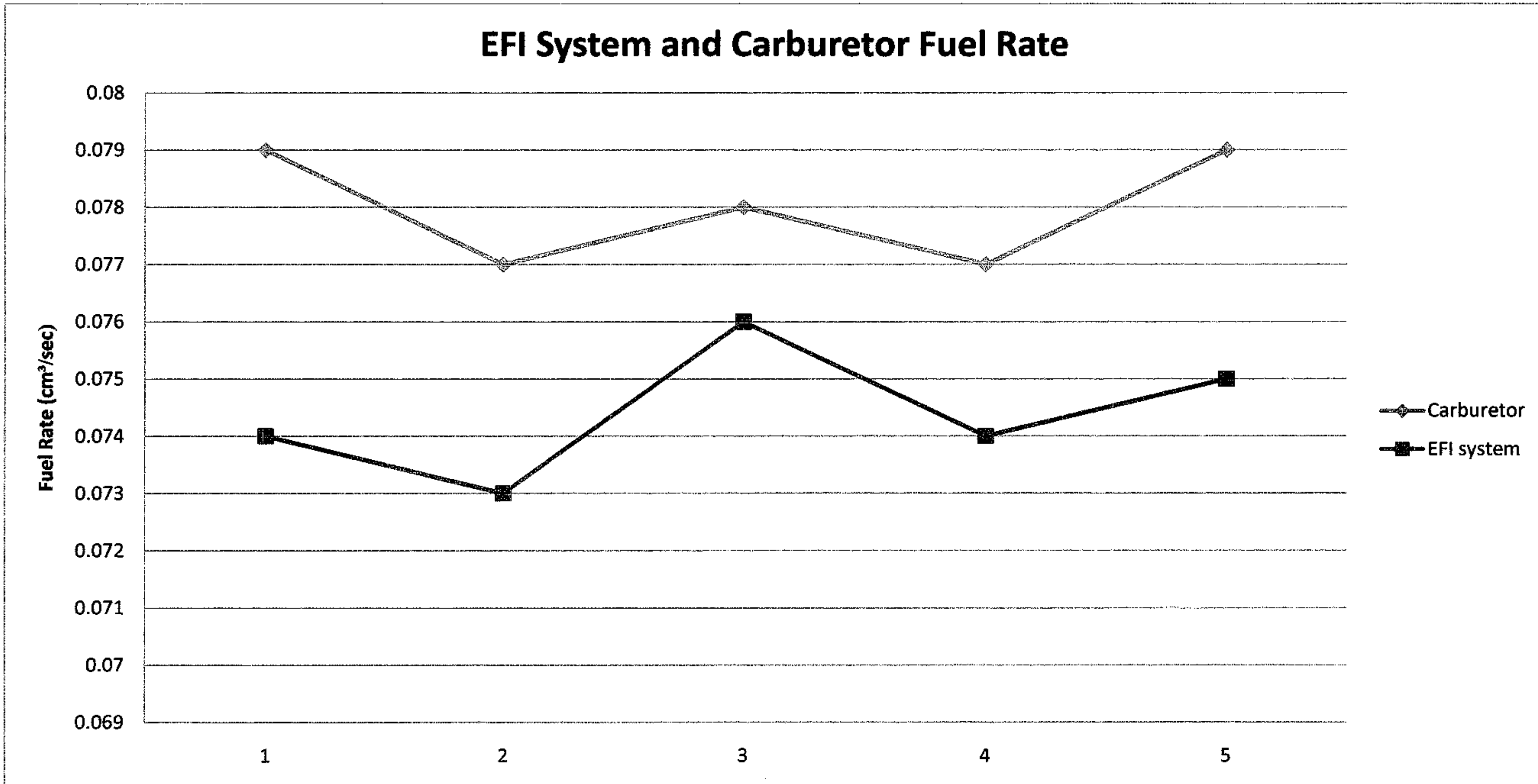


Figure 4.1.2: Graph of fuel rate versus test run for EFI system and carburetor

From the graph (c), in overall the value fuel flow rate of carburetor is higher than EFI system as overall. This means that **EFI is economical because it takes longer time to empty a full volume of fuel**. For test run 1, the gap between the EFI and carburetor is $0.005\frac{cm^3}{sec}$ which is the highest gap as compared to other test runs. Next, the lowest gap for fuel rate data is at test run 3 which only give $0.002\frac{cm^3}{sec}$. This **fluctuation of data is caused by many errors** such as working performance of the EFI system itself, pending of the clock ticker to record the time and the surrounding condition that can affect the engine performance. Other than that, the size of opening hole of injector is quite big for this system. To elaborate, higher pressure is required to give full atomization to the fuel sprayed. For the right situation, EFI fuel flow rate can be reduced if we increase the pressure of fuel of use smaller hole of injector. This can be prove by Bernoulli principle which tell us that an increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy. From this principle, when smaller hole of injector was used, the spray pattern may result in the formation of droplet mists which can be mixed thoroughly with air. With good mixture, only small amount of fuel is required for combustion. However there is a limit of how much air fuel ratio (lean). This can be referred to next data at 4.1.4.

4.1.3 Specific Fuel Consumption

Specific Fuel Consumption is the ratio of fuel rate over net power of the engine. In other words, specific fuel consumption value can be remains similar over a wide range of engine sizes. These numbers only change for different engine designs and compression ratios. For example, a small one cylinder 50 cc four-stroke and a large V8 engine can both have the same SFC number. Function of sfc also is to allow the fuel efficiency of different reciprocating engines to be directly compared. Value for sfc can be calculated using a formula as below:

$$\mathrm{sfc} = \frac{\dot{m}_{\mathrm{f}}}{P}$$

<u>Carburetor</u>

Engine speed = 4000 rpm

Net power = 0.52 kW

Torque = 1.2 Nm

$= 0.05653 \frac{g}{sec} \div 520\ w$

$= 1.087 \times 10^{-4} \times (3.6 \times 10^{6})$

$=391.36 \frac{g}{kWh}$ #

EFI system

Engine speed = 4000 rpm

Net power = 0.52 kW

Torque = 1.2 Nm

$$= 0.0537 \frac{g}{sec} \div 520\, w$$

$$= 1.033 \times 10^{-4} \times (3.6 \times 10^{6})$$

$$=371.78 \frac{g}{kWh} \#$$

From the result above, value of sfc for carburetor is higher which is $391.36 \frac{g}{kWh}$ compare to $371.78 \frac{g}{kWh}$ for EFI system. **EFI system is more energy efficient because of its sfc's lower value**, in other word, **EFI needs less amount of fuel (source) to produce the same amount of power like carburetor did**. For graph (b), five test run were done and the result shows, EFI is totally lower than carburetor. Test run 1 gives a difference of $20 \frac{g}{kWh}$ for EFI and carburetor reading. Test run 3 is like at the fuel rate graph which gives the smallest gap of 10 $\frac{g}{kWh}$ at this point. The reason is, the data for specific fuel consumption is using the same data at fuel rate calculation. Net power of the engine is assumed to be the same at 0.52 kW. Besides that, engine speed for this test is at 4000 rpm.

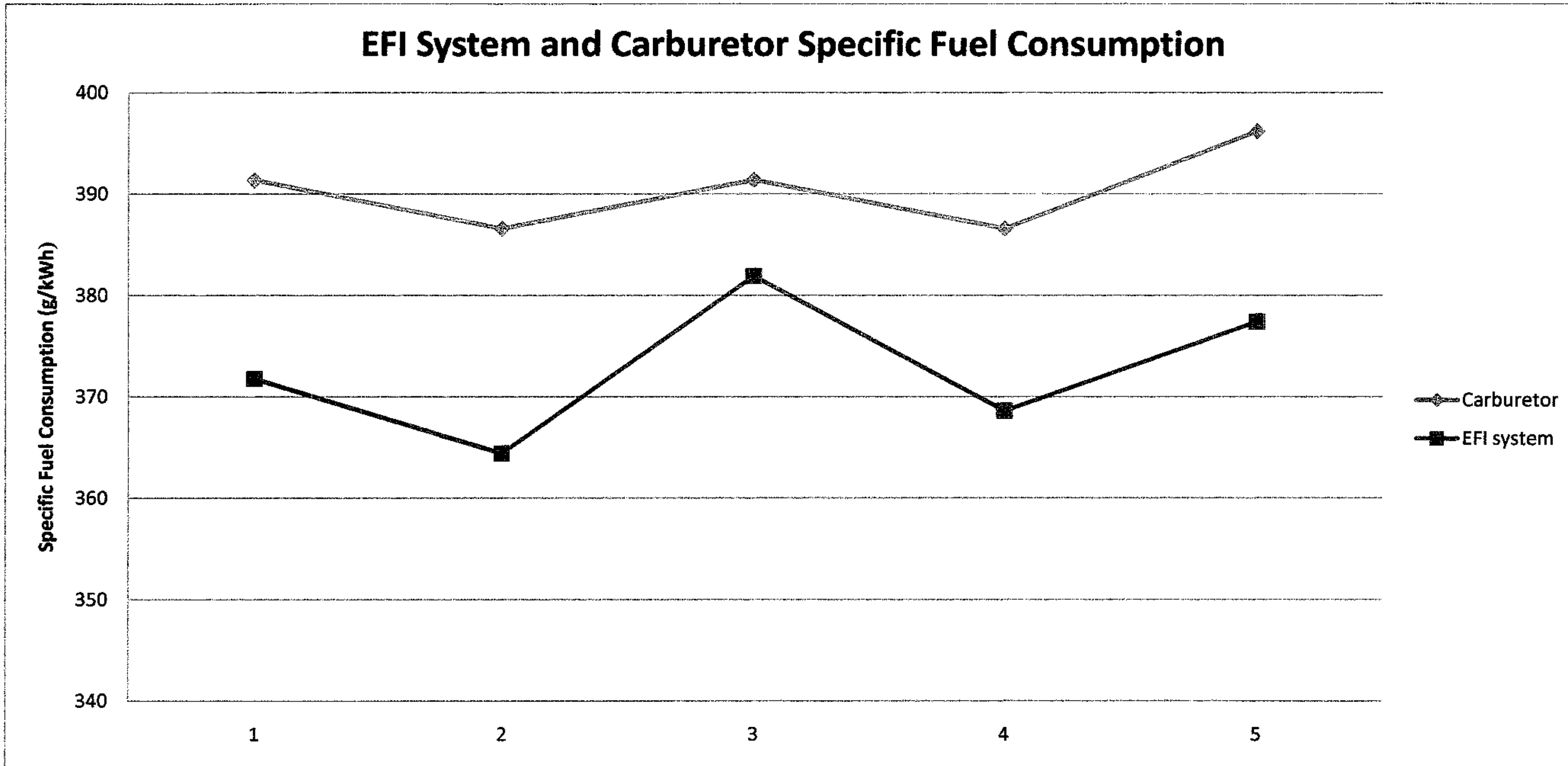


Figure 4.1.3: Graph of Specific fuel consumption versus test run for EFI system and carburetor

d

4.1.4 Injector diameter

Diameter of injector is playing a main role in order to give a better fuel atomization during injection. 2.0 bar of pressure is used before 2.5 bar. The difference between these both value is the atomization of fuel injection that effect the fuel combustion efficiency. Instead of increase the pressure, reduce the diameter of injector will give the same result.

Old injector radius = 0.5 mm = $5 \times 10^{-4}\ m$

To get the new radius, find the area

Velocity for old area =

$$Q = AV$$

$$Q = 0.0537\frac{g}{s}$$

$$A = 1.96x10^{-7}m^2$$

$$V = 2.78x10^5 ms^{-1}$$

using Bernoulli equation,

$$\frac{1}{2}\rho v^2 + \rho gz + p)old = \frac{1}{2}\rho v^2 + \rho gz + p)new$$

$$\frac{1}{2}(0.75)(2.78x10^5)^2 + \rho gz + 200)old = \frac{1}{2}(0.75)v^2 + \rho gz + 250)$$

$v = 3.71x10^5$= new velocity

New area :

$Q = AV$

$0.0537 = A(3.17x10^5)$

$A = 1.432x10^{-7}$

$A = \pi r^2$

$\boldsymbol{r\ new = 2.135\ x\ 10^{-4}m}$

Instead of using 2.5 bar of pressure, reducing the diameter from $5x10^5$m to $4.2\ x\ 10^{-4}m$ at 2.0 bar would give the same fuel velocity.

4.1.5 Fuel Combustion Efficiency

$$\eta_f = \frac{W_c}{m_f Q_{HV}} = \frac{P}{\dot{m}_f Q_{HV}}$$

Heating value (Q_{HV}) =44.40 $\frac{Mj}{kg}$ for gasoline

<u>Carburetor</u>

$=\left(\frac{520}{0.05653}\right) \times (44400)$

$=0.207 \times 100\%$

$=20.7\%$

<u>EFI System</u>

$=\left(\frac{520}{0.0537}\right) \times (44400)$

$=0.218 \times 100\%$

$=21.8\%$

Fuel combustion efficiency is the meter of how well the combustion of the fuel in engine combustion. To get the idea, **higher percentage** means the **combustion of the fuel is better** or more atomization of fuel is burned and successfully change to the power of the engine and not disappear in the surrounding as insignificant produced gases like nitrogen oxide that can be harmful to the environment. From the calculation above, EFI system gives a **better fuel combustion efficiency, 21.8%** compare to **carburetor, 20.7%**. Hence, **EFI is better in environmental friendly because it gives more complete combustion and decrease the production rate of harmful gases to the surrounding.**

For extra details, fuel consumption at three different engine speeds were calculated. The function of this calculation is wants to know the specific fuel consumption at three different conditions. As stated below, fuel consumption for low engine speed (taking corner), medium engine speed (straight track) and high engine speed (full throttle to overtake) were calculated. In SEM race, it is important to know these three values in order to get the idea of overall fuel consumption. Net power and net torque of the engine are based on engine specification graph.

At **low engine speed (taking corner plus braking)**, the fuel consumption was:

Engine speed = $2000\ rpm$

Net power = $0.15\ kW$

Torque = $1.1\ Nm$

$= 0.015 \frac{g}{sec} \div 150w$

$= 1.011 \times 10^{-4} \times (3.6 \times 10^{6})$

$= 363.87 \frac{g}{kWh}$

At **medium engine speed (straight track ; gliding)**, the fuel consumption was

Engine speed = $4000\ rpm$

Net power = $0.52\ kW$

Torque = $1.2Nm$

$= 0.0537 \frac{g}{sec} \div 520w$

$= 1.033 \times 10^{-4} \times (3.6 \times 10^{6})$

$= 371.78 \frac{g}{kWh}$

At **high engine speed (full throttle to overtake)**, the fuel consumption was

Engine speed = $5500\ rpm$

Net power = $0.80\ kW$

Torque = $1.6Nm$

$= 0.0872 \frac{g}{sec} \div 800w$

$= 1.090 \times 10^{-4} \times (3.6 \times 10^{6})$

$= 392.52 \frac{g}{kWh}$

As a conclusion, specific fuel consumption is giving the highest reading at high speed engine, which is $392.52 \frac{g}{kWh}$ followed by medium speed engine, as we can see, the value is $371.78 \frac{g}{kWh}$ and the lowest specific fuel consumption is at low engine speed where the value is $363.87 \frac{g}{kWh}$.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Engine Honda GX 35 with Electronic Fuel Injection was giving a better fuel rate, specific fuel consumption and fuel combustion efficiency. For specific fuel consumption, using the same engine with different fuelling system, gave 5% of economical saving for EFI system compare to carburetor (in term of fuel rate). In Shell Eco Marathon, with combination to suitable transmission system (CVT) can lead to a better efficiency which will reduce the fuel consumption.

Study on the compatibility of the engine and the EFI systems component needed to match perfectly with the needs of efficiency, reliability, flexibility and size of these two components. FC Design Fi-M Digital Fuel Injection System that being mounted onto Honda GX 35 was not fully utilized. In this project, only fuel injector and photoelectric sensor being used which to know the time for fuel injector to perform its job. Other sensor was not used like the oxygen sensor because of the limitation of engine size and fuel injection system itself. Fuel injector is quite big and need higher pressure in order to increase the rate of atomization of fuel. To overcome the problem, it is suggested to get a smaller injector or increase the pressure.

As a conclusion, the objectives of this project have been achieved throughout the study of EFI system and conversion processes. Fuel consumption was met the target where can be save just up to 5% on the several engine run.

5.2 Recommendation

In order to decrease of the fuel consumption, beside change the carburetor to EFI system, there are many ways can be done to accomplish the target. For example:

5.2.1 Run the prototype vehicle at perfect speed according to the engine torque.

For engine GX 35, the highest torque was at 5250 rpm. According to the graph of net torque, at 5250 rpm of engine speed, maximum toque was produced and the value was 1.6 Nm. With the engine speed of 5250rpm, prototype speed was 36km/h and suitable for this engine and weight of the body which was 60 kg.

5.2.2 Heating Ventilation.

Engine performance can be drop because of high temperature. Based on the experience at Sepang, the surrounding temperature was high. Heating ventilation was important in order to overcome this problem. There are many ways to do this task, for example:

- Install fan at engine area
    - Fan can be installed in order to give continuously air flow into the engine. Because of the movement of the air, the surrounding temperature of the engine will drop compare to original condition. Higher air movement rate will continuously change the hot air from the engine with cooler surrounding air and it will helps to cooling down the engine. Cooler engine will give maintained performance to the prototype vehicle.
    -

- Body with air inlet
  - Air inlet from outside the body can be designed and fabricated just to give outside air flowing into the engine bay. When the prototype vehicle moving, the outside air will be force into the engine bay. This action will give air movement and will cooling down the engine. Higher speed of the vehicle, higher the air movement rate into the engine. It will give a good result to the engine performance; beside avoid the engine to face any damaged because of high temperature.

5.2.3 Exhaust system.

Exhaust system that being used can be improve by using straight piping system in order to reduce the back pressure to the engine. Back pressure will increase the engine load work because the exhaust's gases cannot be easily leave the engine. This will cause drop in engine performance itself.

5.2.4 Bearing, Grease and Low Friction

Use high speed bearing at the crankshaft to reduce friction. Friction will cause mechanical inefficiency and will increase the load to the engine. The use of grease will also help in term of reducing friction. Friction also will inhibit the smooth movement for the vehicle.

REFERENCES

1. http://www.honda-engines.com/engines/gx35.htm
2. http://auto.indiamart.com/auto-technology/auto-tech-fuel-injection.html
3. Crouse, William Harry 1993, Carburetor, "AUTOMOTIVE MECHANICS" *Book of Automotive Technology Series*, 10th Edition , 261-262
4. http://en.wikipedia.org/wiki/Electronic_fuel_injection
5. Crouse, William Harry 1993, Electronic Fuel Injection, "AUTOMOTIVE MECHANICS" *Book of Automotive Technology Series*, 10th Edition , 224
6. http://www.atvmagonlineblog.com/wp-content/uploads/2009/03/598px-carburetor_svg.png
7. http://fcdesign.free.fr/en/index.html
8. http://mesin-its-team.blogspot.com/2010/03/sapu-angin-i.html
9. http://www.sem-ui.web.id/