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Small Engine Performance Optimization for Power and Fuel Consumption Improvement of a Simple Vehicle

by

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

(Dr. Zainal Ambri Bin Abdul Karim)

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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.

MOHAMAD SYAHMIE BIN KAMSUL

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ABSTRACT

This report discusses the preliminary research done and basic understanding of the chosen topic, which is **Small Engine Performance Optimization for Power and Fuel Consumption Improvement of a Simple Vehicle**. The objective of the project is to find the optimum engine performance of a single cylinder engine which suggests utilizing a minimum amount of petrol without compromising the performance of the engine. The challenge in this project is to find the most suitable way to install the EFI (electronic fuel injection) and to calibrate the EFI module to work efficiently at different conditions. The reason to change the standard carburetor with an EFI system is to obtain more fuel efficiency and power improvement because it is proven that better fuel and air supplying into the intake manifold will give the engine more power and fuel efficiency. An EFI system provides correct mixture of fuel and air compare to the carburetor with the help of electronic system thus it increased engine performance. Lab testing was performed for the designed EFI system to create the suitable match between the engine and the fuel injection system. The system was tested for its workability, performance and resistance to high performance condition. The result from the experiment shows an improvement of 3 to 4% of improvement of fuel consumption. Further detail can be read in this report.

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CHAPTER 1
INTRODUCTION

1.1 Background Of Study

The engine use for this project is HONDA GX160, a 4 stroke engine, overhead cam single cylinder. The engine will be fitted with a new fuel injector to replace the standard carburetor. The specification of the engine is [1]:

Engine type	Air-cooled 4-stroke OHV
Bore X Stroke:	68 X 45 mm
Displacement:	163 cm^3
Compression Ratio:	8.5:1
Lamp/Charge Coil Options	25W, 50W / 1A, 3A, 7A
Net Horse Power Output:	3.6 Kw (4.8 HP) at 3600 rpm
Net Torque:	10.3 Nm (7.6 Lbs Ft) at 2500rpm
PTO Shaft Rotation	Counterclockwise (from PTO shaft side)
Ignition System:	Transistorized Magneto Ignition
Starting System:	Recoil Starter
Carburetor:	Float Type
Lubrication System:	Splash
Governor System	Centrifugal Mechanical
Cooling System:	Forced Air
Air Cleaner:	Dual element, Oil Bath, Semi-Dry Type
Oil Capacity:	0.6 L
Fuel Tank Capacity	3.1
Dimensions (L X W X H)	305mm X 341mm X 318mm
Dry Weight:	13~18 Kg

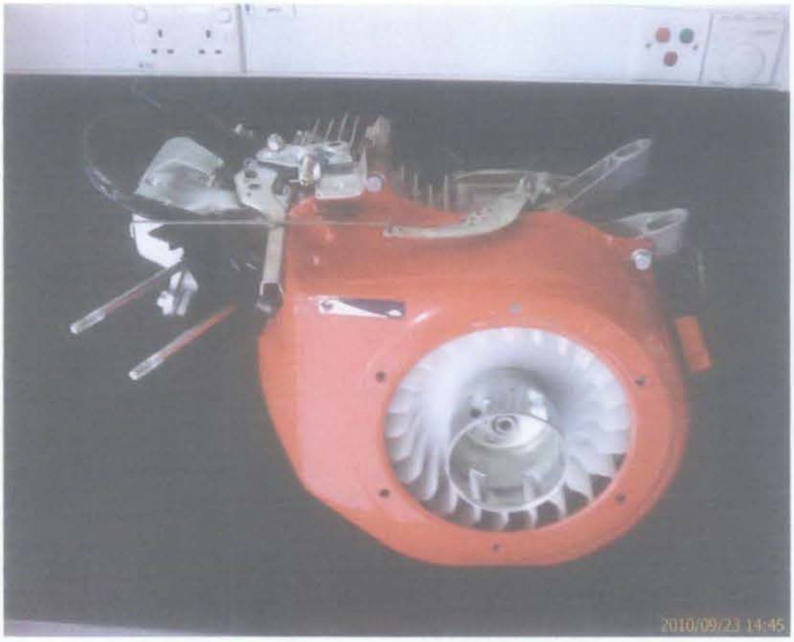


Figure 1: Front view

Figure 2: Rear view

Figure 3: Side view

Figure 4: Exhaust port

Figure 1-4 show the engine from front view, rear view, side view and the exhaust port. In the front view figure, we can see there is a small white rotor inside the red casing that connect to the engine shaft. The rotor provide an air cooler system to the engine thus prevent the engine from overheat during long period operation. The red casing provides a direction for the airflow from the rotor towards the engine shaft. In the rear view figure, there is the exhaust port and the engine shaft. This engine is an overhead valve type. This is clearly indicated at the valve cover in Figure 3. Figure 4 show exactly where is the exhaust port location.

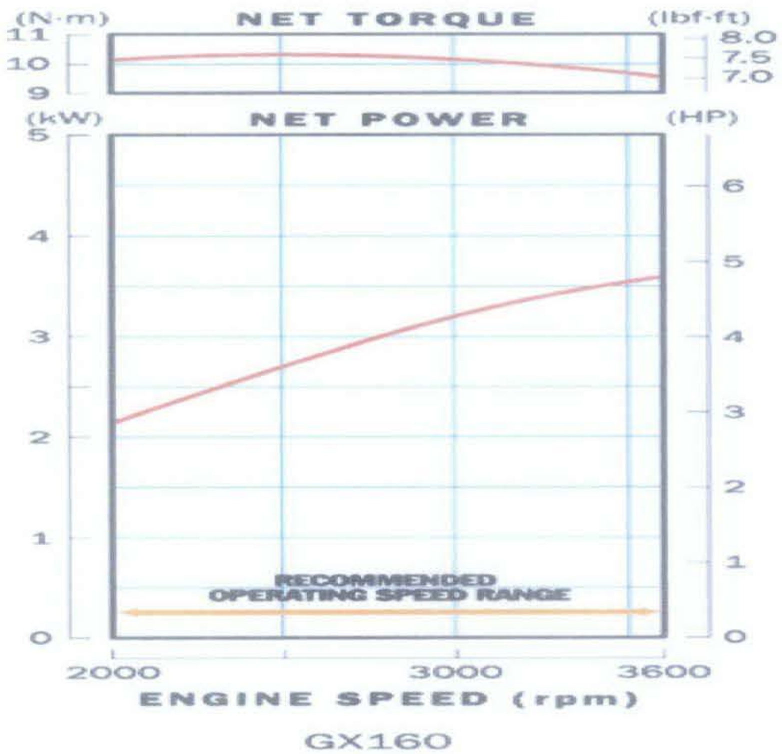


Figure 5: Engine torque and power for Honda GX160 [1]

Figure 5 shows the engine torque and power characteristic. The graph shows an operating engine speed at idle mode between 2000 to 3600 revolution per minutes (rpm). At the idle mode speed, the engine produce power between 3 to 5 horse power which is gradually increase as the engine speed increase. As for the torque value, the engine achieves good torque at lower engine speed and the maximum value record at the graph is around 10.3 N.m at 2500 rpm.

achieves good torque at lower engine speed and the maximum value record at the graph is around 10.3 N.m at 2500 rpm.

This engine will operate a prototype 3 wheel vehicle. This engine is require to run the vehicle at an average speed of approximately 30 km/h. The power estimation required for this simple vehicle will be approximately 1.0 HP and the torque estimation to achieve this power will be approximately 1.5 N.m. With this engine, it provides more than the power the simple vehicle needed where it can run at lower engine speeds as ideal operating speed.

1.2 Problem Statement

The performance of an engine can be increased by changing the standard carburetor with an EFI (electric fuel injection) system. The problem with the EFI is it needs a modification in order to fit with the engine inlet port. The electronic control of the fuel injection also needs to be modified to fit the new configuration. This is because the EFI system was not build for the engine. Further study need to be carried out to fit the EFI system with the engine. After the system is manage to be install onto the engine, several test will be carried out to make sure the implementation of the fuel injection is correct and meet the objective of this project. Therefore, this project aims to modify the engine with an electronic fuel injection that will optimize the fuel consumption thus increase the performance of the engine.

1.3 Objective

The main objectives of this research are:

- To increase the performance of the single cylinder engine by replacing the standard carburetor with injection system.
- To determine the suitable synchronization of the fuel injection system with the engine.

1.4 Scope of Study

The scope of study for this project will be in two part which is part one is FYP 1 and part two is FYP 2 as below:

FYP 1

Main focus is to investigate the how to install a proper EFI system to the Honda GX160 engine. Also to prepare the tools and component require to mounting the EFI system to the engine.

FYP 2

Upon completion of the modification, the engine is tested in two areas that are the performance of the engine with the new fuel injection system and the fuel consumption of the engine. Once the fuel injection system are fitted to the engine intake, the engine is tested to observe the operation of the new fuel injection system. Finally the best configuration for the fuel injection to work on the engine is determined. Other option for the engine performance beside the fuel injection system is tested during the project.

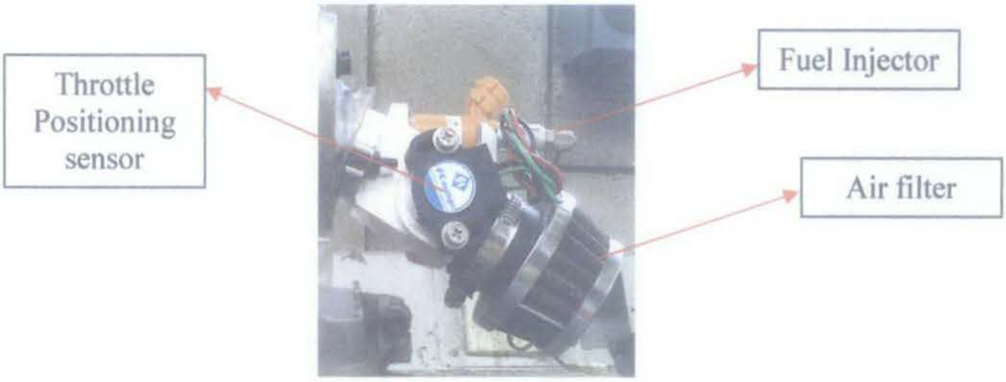
CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The potential for improving the fuel economy of conventional, gasoline-powered automobiles through optimized application of recent technology advances is analyzed. Results are presented at three levels of technical certainty, ranging from technologies already in use to technologies facing technical constraints (such as emissions control problems) which might inhibit widespread use [2]. A fleet-aggregate, engineering-economic analysis is used to estimate a range of U.S. new car fleet average fuel economy levels achievable given roughly 10 years of lead time. Technology cost estimates are compared to fuel savings in order to determine likely cost-effective levels of fuel economy [2].

The air fuel ratio in a carburetor system is varies according to the intake air temperature and density. This condition makes accurate control of the correct mixture strength virtually impossible. In contrast, the EFI system uses a number of sensors to monitor all conditions that will affect the air fuel ratio and it will respond quickly to the changing operating conditions. This means that an accurate control of the mixture is possible. The ECM is programmed to calculate basic fuel injection duration. The ECM will actually hold the injector open, and is usually measured in milliseconds(ms) [3]. Data collected from various types of sensors such as Throttle Positioning System (TPS), Manifold Absolute Pressure (MAP) and oxygen sensors will be used by the ECM to modify the figure of mixture so that the quantity of injected fuel is computed exactly for all conditions of temperature, speed and load.

2.2 Throttle Body Injection Intake Manifolds



Throttle Body Injector Unit

A throttle body fuel injector forces finely divided droplets of liquid fuel into the incoming air to form a combustible air fuel mixture. These droplets start to evaporate as soon as they leave the throttle body injector nozzles. The droplets stay in the charge as long as the charge flows at high velocity. Separation of the droplets from the charge as it passes through the manifold occurs when the velocity drops below 50 feet per second. Intake charge velocity at idle speeds is often below this value [3]. When separation occurs, at low engine speeds, extra fuel must be supplied to the charge in order to have a combustible mixture reach the combustion chamber. A single injector injects fuel into a distributing intake manifold is much like the same as a carburetor system. Although the injection of fuel is much more precise, the problem of manifold heating becomes critical and the warm up period must be carefully controlled if drivability is not be impaired [4]. Furthermore, the manifold is said to be wet type. This term means that fuel is present in the intake manifold.

2.3 Energy and Power

Energy used to produce power comes from the chemical energy in fuel. The chemical energy is converted to heat by burning process at a controlled rate. Heat release in the combustion chamber raises the temperature of the combustion gases within the chamber. This process increases the pressure of gas in the chamber [4]. The pressure increase in the chamber is applied on the piston to produce a usable mechanical force which then converted to mechanical power.

2.4 Bore and Stroke

The diameter of a cylinder is called the bore, the larger the bore, the greater the area on which the gases have to work. Pressure is measure in units such as pounds per square inch (psi). The greater the area, the higher force exerted by the pistons to rotate the crankshaft. While for stroke, the distance of the piston travels down in the cylinder is called the stroke [4]. The longer stroke, the greater the amount of the air fuel mixture that can be drawn into the cylinder. Thus result in more force when the air fuel mixture ignited.

2.5 Compression Ratio

Compression ratio of an engine is an important consideration in EFI system. The definition of the compression ratio is the ratio of the volume in the cylinder above the piston when the piston is at the bottom of the stroke (Bottom Dead Center) to the volume in the cylinder above the piston when the piston is at the top of the stroke (Top Dead Center).

Lower compression	**Higher compression**
Lower power	Higher power
Poorer fuel economy	Better fuel economy
Easier engine cranking	Harder to crank engine
More advanced ignition timing possible without spark knock(detonation)	Less ignition timing required to prevent spark knock(detonation)

CHAPTER 3
METHODOLOGY

3.1 Project Identification

3.1.1 Throttle Body Injection position

Figure 6: Throttle Body Injector (TBI)

This is the throttle body injector that was replaced with the carburetor system. The position of the injector from the intake manifold is vertical. This will make sure the fuel is inject straight to the burning chamber when the valve is open.

Figure 7: intake manifold

Figure 8: TBI

Figure 7 show the position of the intake manifold that was place with a throttle body injection (TBI) where the injector is in a horizontal position. A mounting plate need to be prepare to place the throttle body injection to the intake manifold.

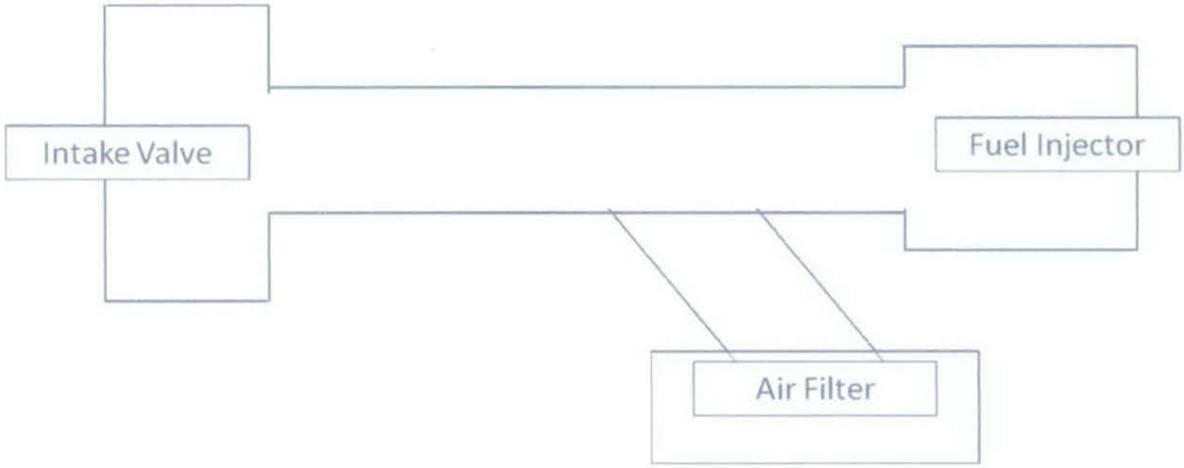


Figure 9: Throttle Body Injection with intake manifold schematic diagram position

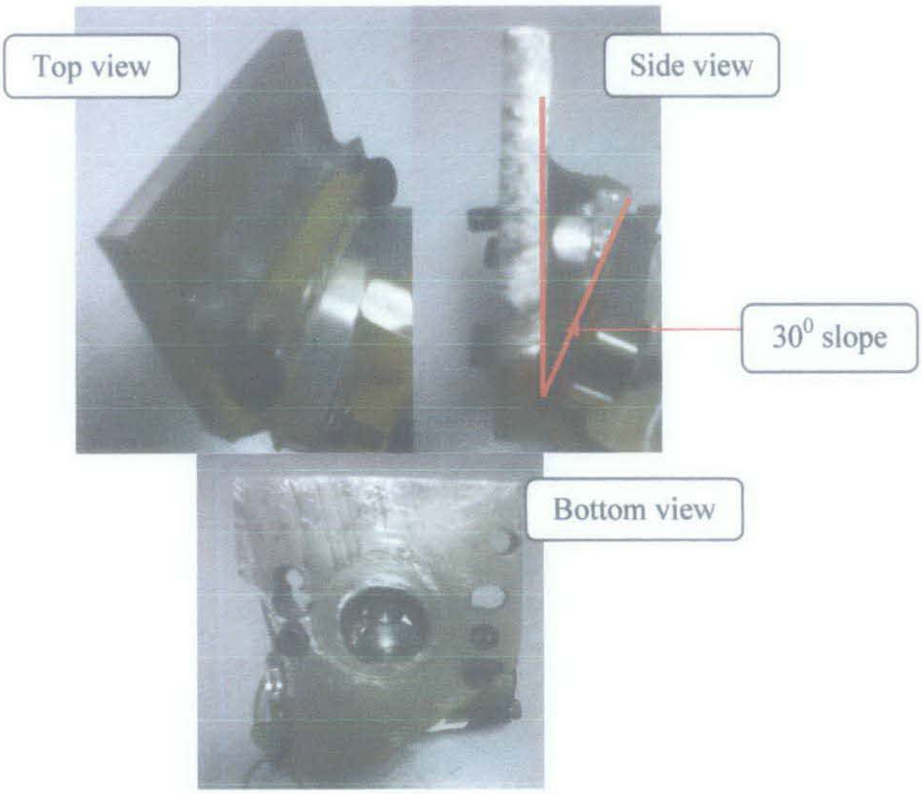


Figure 10: the mounting plate for the throttle body injection

The mounting plate for placing the throttle body injection (TBI) to the intake manifold is made from aluminum. In order to get a vertical position for the injector, a 30^0 angle of slope is made on the plate.

3.1.2 Wiring system

Figure 11: The wiring use with the throttle body injector (TBI)

This is the wiring system that was use with the throttle body injector (TBI) where the wiring system consist the ECU unit which will gather the information from the sensors and control the amount of fuel that need to be injected into the intake manifold.

3.1.3 Fuel consumption measurement

Figure 12: The arrangement of the 50mL volumetric pipette to measure the fuel consumption

The fuel consumption measurement was done by using a 50mL volumetric pipette. The measurement wass start with 5 different engine speed of 1700, 1900, 2100, 2300 and 2500 rpm. The measurement will be base on time over volume. Then, the experiment will look for fuel rate consumption (cm^3/sec). For every 10mL, the time was record in second. The first setup will be use to measure the fuel consumption on the carburetor system. Then the second setup was use to measure the fuel consumption on the throttle body injector (TBI) system. The different will be determined from the graph after the experiment was conducted.

3.2 The Gant Chart

3.2.1 Final Year Project 1 (FYP 1)

No.	Activities/Week	1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Receive the FYP title															
2	Discuss and update progress with Supervisor about the project.															
3	Researching on project information.															
4	Submission on preliminary															
5	Project working progress - research on EFI system.							MID SEMESTER BREAK								
6	Seminar											21/9/10				
7	Submission on the progress report. – finalizing design											24/9/10				
8	Project working Progress – EFI mounting and modification.															
9	Submission of Interim Report Final Draft													1/11/10		
10	Oral presentation															

3.2.2 Final Year Project 2 (FYP 2)

No.	Activities/Week	1	2	3	4	5	6	7	MID SEMESTER BREAK	8	9	10	11	12	13	14	15
1	Prepare the engine for testing	■															
2	Testing for engine fuel consumption with carburetor system.		■	■													
3	Update journal, abstract, writing				■	■	■	■									
4	Testing for engine fuel consumption with TBI									■	■	■	■				
5	Submission of progress report									■		15/7/11					
6	Analyzing the comparison between carburetor and EFI										■	■					
7	Pre-EDX												■	1-5/8/11			
8	Submission of draft report													■	8-12/8/11		
9	Submission of dissertation (soft bound)												15-19/8/11		■		
10	Submission of technical paper														■		
11	Oral presentation												22-26/8/11			■	
12	Submission of dissertation (hard bound)														2/9/11		■

3.3 Specific Overall Project Activities

1. Research and problem background
    - Study the common injection system and the different with carburetor system
    - Gathering of information from internet, books and journals on the EFI system and study how to install and operate the EFI system

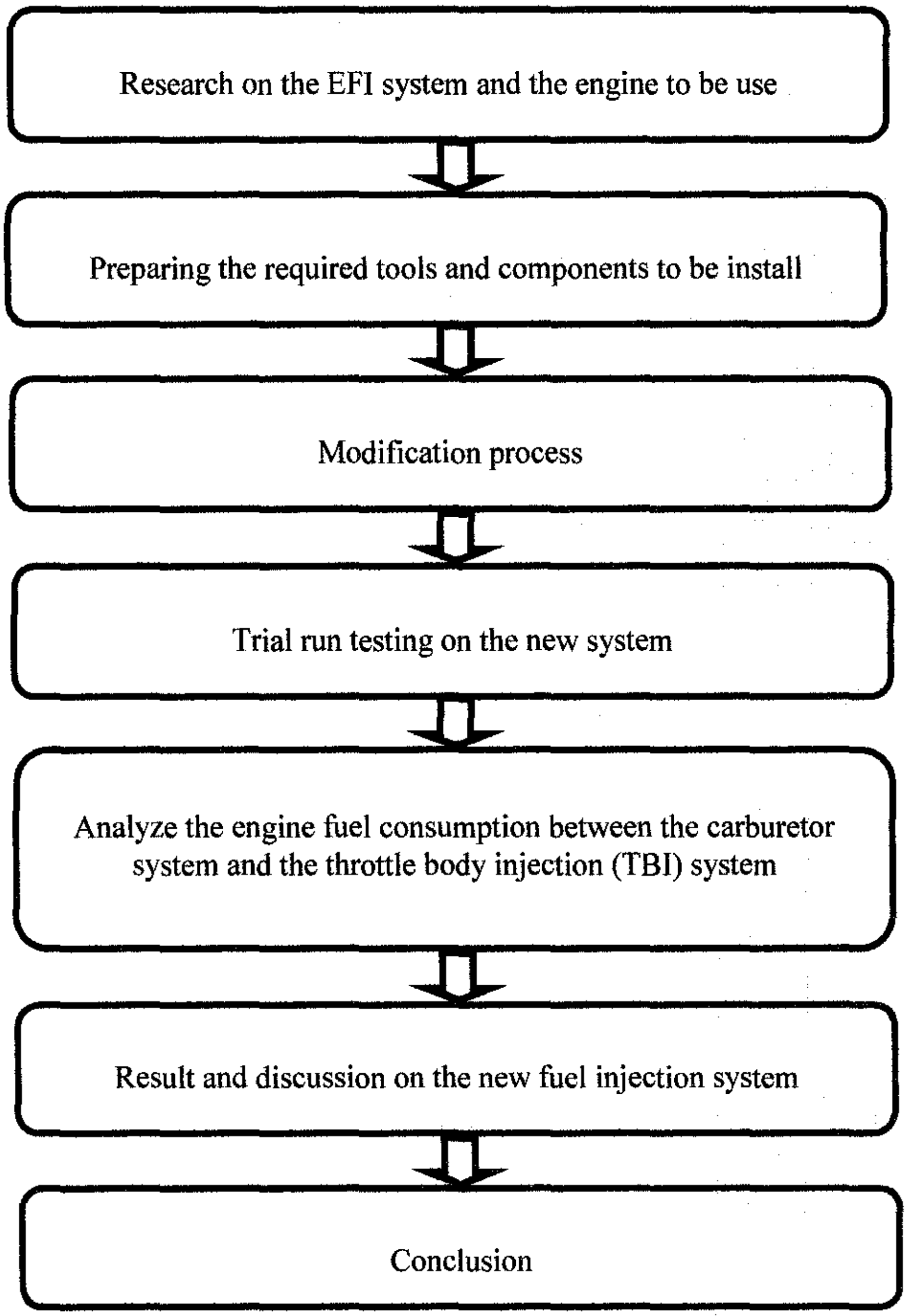
2. Engine and EFI kit selection
    - The engine use in this project is HONDA GX160. The engine usually use for lawn mower machine or pump machine
    - The EFI system that will be use on to the engine come from company FC Design.

3. Fabrication
    - Prepare the mounting plate
    - Set up the wiring system
    - Set up the ECU program

4. Testing and analysis
    - Testing the fuel consumption between the carburetor system and throttle body injection (TBI) system and analyze from graph after the experiment

5. Review
    - Revise and analyze the data received from testing and make the comparison

3.4 Project Execution Plan



CHAPTER 4
RESULTS AND DISCUSSION

4.1 Procedure

Engine specification that we use is 160cc, 4 stroke engine. This engine provides good performance with the initial system where the fuel consumption rated at 1.4L/h which the engine achieves good 4HP at below 3600 rpm. The EFI system has been fitting to the intake manifold. The fuel consumption of the engine at different engine speed was performed experimentally. The following are the procedure for the experiment.

Step of the experiment:

1. Setup the engine with carburetor system
2. Setup the 50ml pipette as the fuel tank
3. Fill in the fuel in the pipette
4. Start the engine
5. Start the stopwatch to measure 10ml fuel consumption at engine speed 1700 rpm
6. Stop the stopwatch after 10ml of fuel is finish
7. Repeat the time measurement until 5 sets
8. Repeat procedure 1 to 7 with engine speed at 1900 rpm, 2100 rpm, 2300 rpm, and 2500 rpm respectively.
9. Continue and repeat procedure 2 to 8 with throttle body injection (TBI) system
10. Plot the table and graph

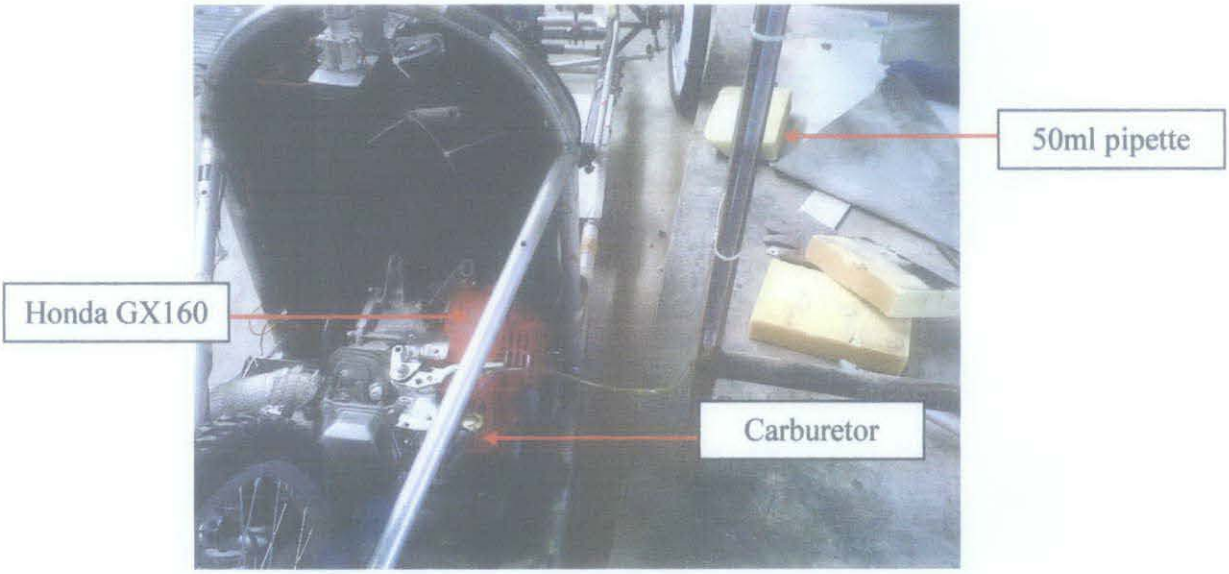


Figure 13: Setup for the experiment with carburetor system

Figure 14: Setup for the experiment with TBI system

4.2 Results

Table 1: Experiment of engine speed at 1700 rpm

	Volume (ml)	Time with carburetor system (seconds)	Time with TBI system (seconds)
1	10	141	147
2	20	141	146
3	30	142	148
4	40	145	149
5	50	143	147

Table 2: Experiment of engine speed at 1900 rpm

	Volume (ml)	Time with carburetor system (seconds)	Time with TBI system (seconds)
1	10	137	142
2	20	136	142
3	30	136	143
4	40	135	141
5	50	137	142

Table 3: Experiment of engine speed at 2100 rpm

	Volume (ml)	Time with carburetor system (seconds)	Time with TBI system (seconds)
1	10	131	136
2	20	132	137
3	30	131	137
4	40	133	135
5	50	132	136

Table 4: Experiment of engine speed at 2300 rpm

	Volume (ml)	Time with carburetor system (seconds)	Time with TBI system (seconds)
1	10	126	131
2	20	127	132
3	30	126	132
4	40	125	133
5	50	126	132

Table 5: Experiment of engine speed at 2500 rpm

	Volume (ml)	Time with carburetor system (seconds)	Time with TBI system (seconds)
1	10	119	124
2	20	120	125
3	30	118	124
4	40	119	124
5	50	117	125

Average time for fuel consumption with carburetor at 1700 rpm

$$= \frac{141+141+142+145+143}{5}$$

= 142.4 seconds

Average time for fuel consumption with throttle body injection (TBI) at 1700 rpm

$$= \frac{147+146+148+149+147}{5}$$

= 147.4 seconds

Average time for fuel consumption with carburetor at 2500 rpm

$$= \frac{119+120+118+119+117}{5}$$

= 118.6 seconds

Average time for fuel consumption with throttle body injection (TBI) at 2500 rpm

$$= \frac{124+125+124+124+125}{5}$$

= 124.4 seconds

Table 6: average time for fuel consumption between carburetor and throttle body injection (TBI)

No	Engine Speed (rpm)	Fuel Volume (cm^3)	Average time on carburetor (seconds)	Average time on TBI (seconds)
1	1700	10	142.4	147.4
2	1900	10	136.2	142
3	2100	10	131.8	136.2
4	2300	10	126	132
5	2500	10	118.6	124.4

Fuel Rate

$$= \frac{\text{Fuel Volume}}{\text{Time}}$$

Table 7: Fuel rate at given engine speed

No	Engine Speed (rpm)	Fuel Rate on carburetor (cm^3/sec)	Fuel Rate on TBI (cm^3/sec)
1	1700	0.070	0.067
2	1900	0.073	0.070
3	2100	0.076	0.073
4	2300	0.079	0.076
5	2500	0.084	0.080

Calculation on percentage improvement of average time of fuel consumption

At engine speed 1700 rpm

Time different = 147.4—142.4

= 5.0 s

Percentage improvement of average time of fuel consumption

$$= \frac{5.0}{142.4} \times 100\%$$

= 3.5 %

At engine speed 1900 rpm

Time different = 142.0—136.2

= 5.8 s

Percentage improvement of average time of fuel consumption

$$= \frac{5.8}{136.2} \times 100\%$$

= 4.2 %

At engine speed 2100 rpm

Time different = 136.2—131.8

= 4.4 s

Percentage improvement of average time of fuel consumption

$$= \frac{4.4}{131.8} \times 100\%$$

= 3.3 %

At engine speed 2300 rpm

Time different = 132.0—126.0

= 6.0 s

Percentage improvement of average time of fuel consumption

$$= \frac{6.0}{126.0} \times 100\%$$

= 4.7 %

At engine speed 2500 rpm

Time different = 124.4—118.6

= 5.8 s

Percentage improvement of average time of fuel consumption

$$= \frac{5.8}{118.6} \times 100\%$$

= 4.9 %

Graph of engine speed vs time that was plotted from Table 6.

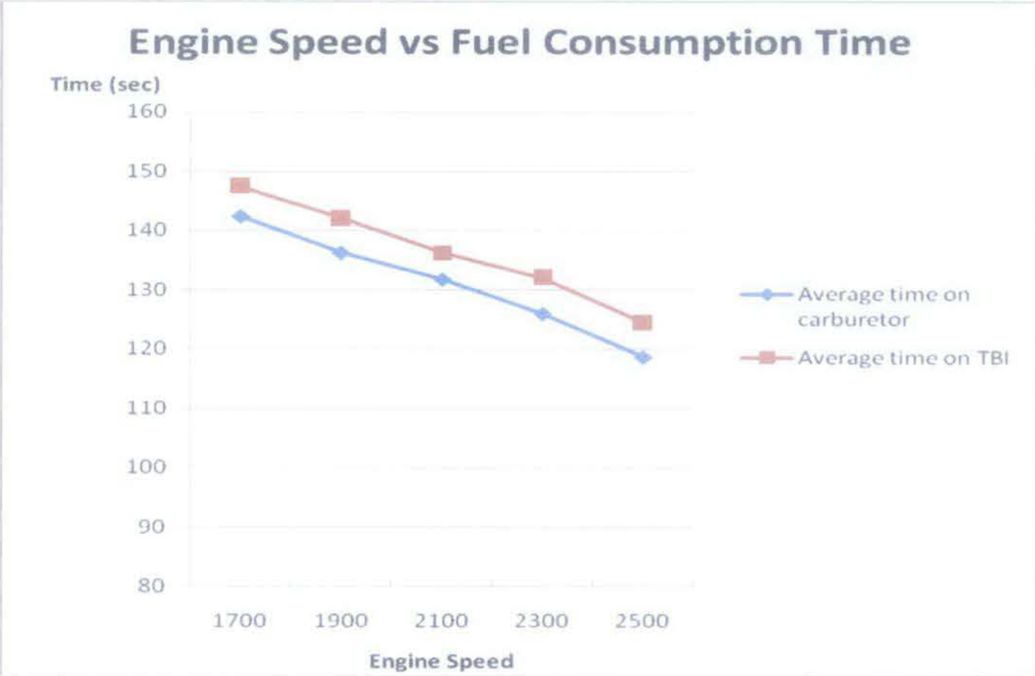


Figure 15: Graph of Engine Speed vs Time of 10ml Fuel Consumption

Graph of engine speed vs fuel rate that was plotted from Table 7.

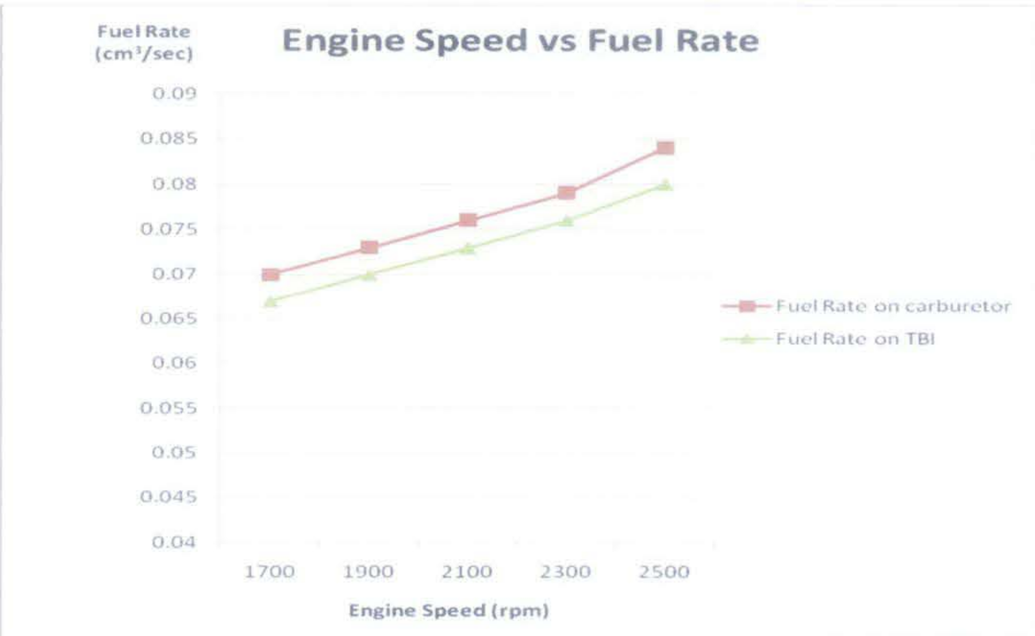


Figure 16: Graph of Engine Speed vs Fuel Rate

4.3 Discussion

From the graph in the result of the experiment, the implementation of the throttle body injection (TBI) system show an improvement of fuel consumption over the carburetor system. The average of time for the engine with carburetor to consume 10ml of fuel that running at an idle speed 1700 rpm is 142.2 sec and the fuel rate at this speed is 0.070 cm^3/sec. With throttle body injection (TBI) system, at idle speed 1700 rpm the average time to consume 10ml of fuel is 147.4 sec and the fuel rate is 0.067 cm^3/sec. The experiment continues with engine speed 1900 rpm where for carburetor system the average time to consume 10ml fuel is 136.2 sec and the fuel rate is 0.073 cm^3/sec. At the same speed with the throttle body injection (TBI) system the average time to consume 10ml fuel is 142 sec and the fuel rate is 0.070 cm^3/sec. Then, continue with engine speed at 2100 rpm, the average time to consume 10ml of fuel for carburetor and throttle body injection (TBI) system is 131.8 sec and 136.2 sec respectively and the fuel rate for carburetor and throttle body injection (TBI) system is 0.076 cm^3/sec and 0.073 cm^3/sec respectively. For engine speed 2300 rpm the average time to consume 10ml of fuel for carburetor and throttle body injection (TBI) is 126 sec and 132 sec respectively and the fuel rate for the both system is 0.079 cm^3/sec and 0.076 cm^3/sec respectively. For engine speed 2500 rpm the average time to consume 10ml of fuel for carburetor and throttle body injection (TBI) system is 118.6 sec and 124.4 sec respectively and the fuel rate for both system is 0.084 cm^3/sec and 0.080 cm^3/sec. These values in average time for fuel to be consume and fuel rate show a different direction in the graph as the speed of the engine increase.

In the engine speed vs time graph, as the engine speed increase, the time to consume 10ml of fuel decrease. This is because the faster the engine run, more fuel is needed to increase the speed. At the speed of 1700 rpm, the torque record for the both system carburetor and throttle body injection (TBI) is around 8 N.m. While from the engine speed vs fuel rate graph, it shows that improvement in fuel consumption. From the graph of engine speed vs fuel rate, by percentage there is 4.3 % of improvement of fuel consumption. As the engine speed increase the fuel rate is also increase but the fuel rate of the throttle body injection (TBI) is slightly reduce compare to the fuel rate of the carburetor system. This is because the fuel injector provides a constant amount of fuel to be injected. From the calculation on percentage improvement of average time of fuel consumption which gives value of 4.7% and 4.9% of improvement, it can be conclude that the optimum fuel consumption is when the engine speed operates around 2000 rpm to 2500 rpm with torque around 10 N.m.

Figure 17 below show the setting of the throttle body injection (TBI) system on the Honda GX 160 engine.

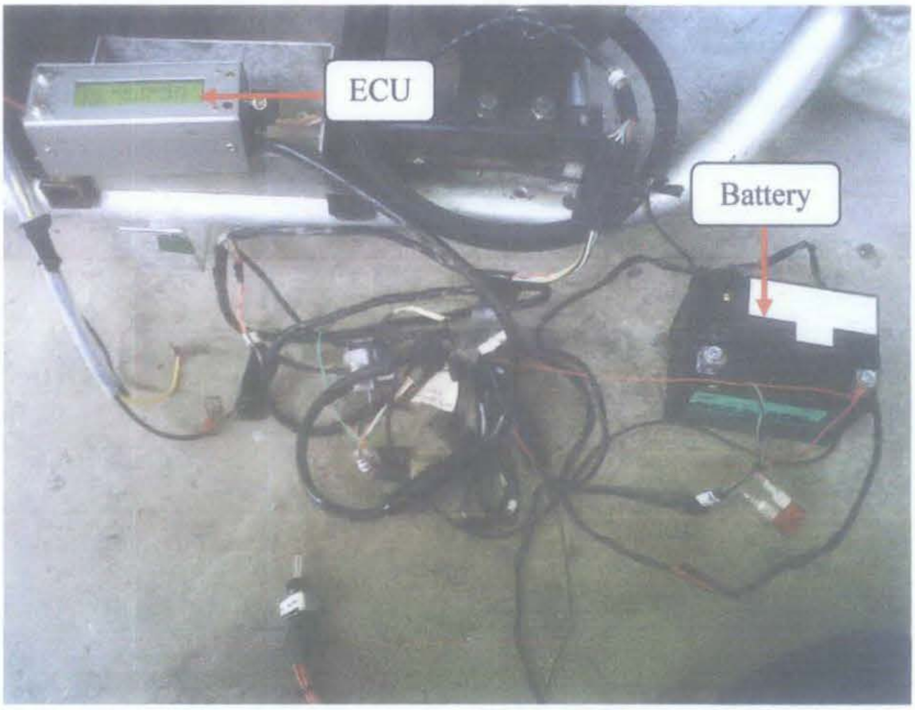


Figure 17: the wiring setup with electrical control unit (ECU)

The wiring system is a complete fuel injection set from the FC Design company. The ECU and the throttle body injection (TBI) need a 12V of battery to be operated. The diagram of the connection can be seen from the diagram below. The wiring only include 1 sensor which is photoelectric sensor that use to detect the rotation of the dummy at the engine shaft that will trigger the injector during the opening intake valve.

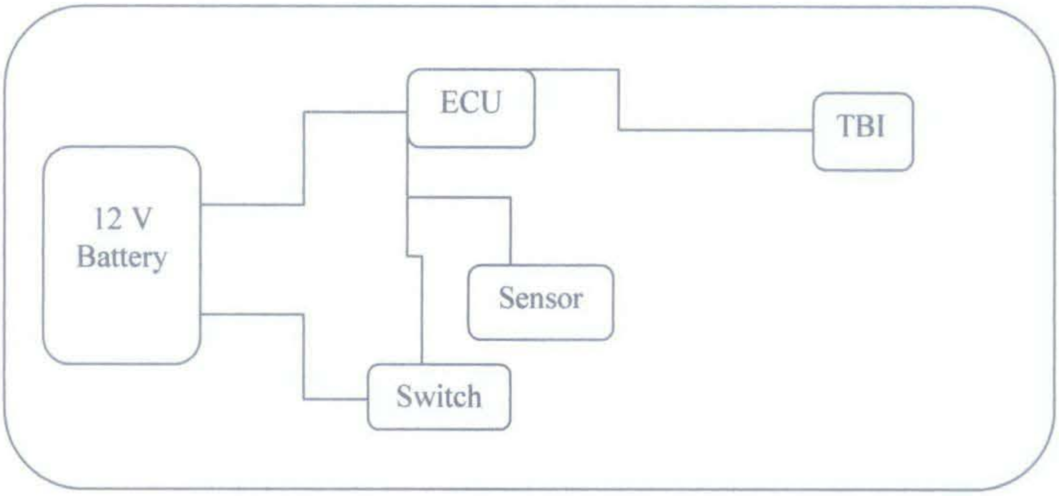


Diagram of the wiring connection

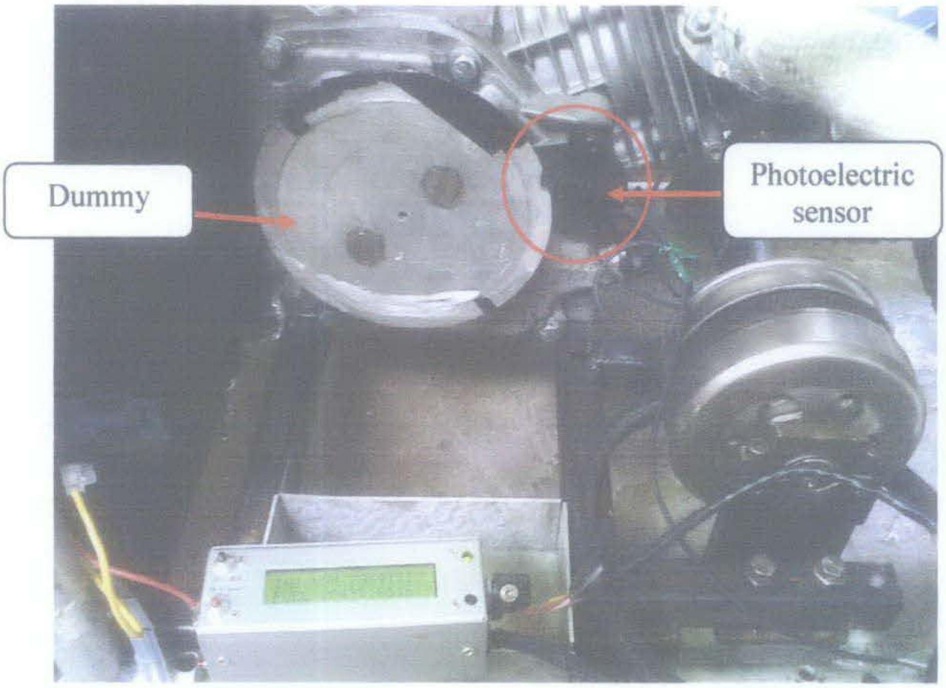


Figure 18: the placement of the sensor for injection signal at the engine shaft

Figure 19: the vertical position of injector at the intake manifold

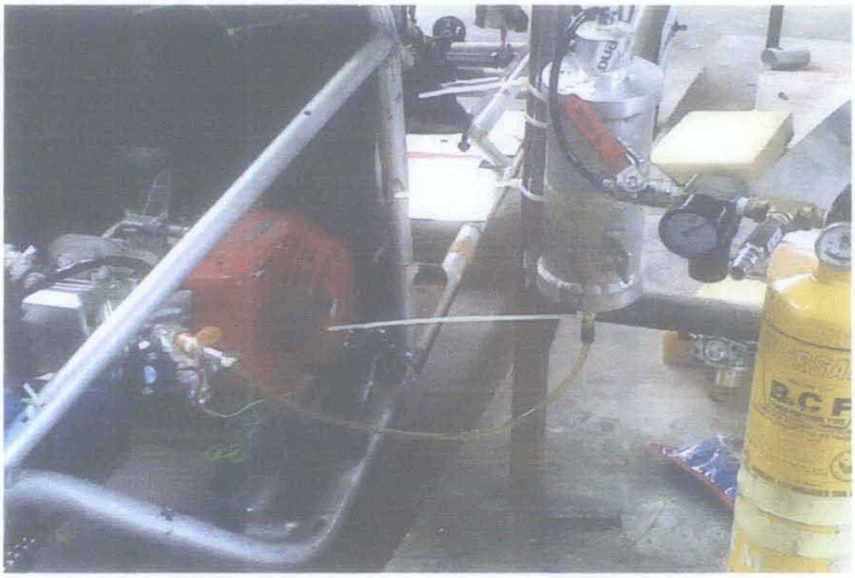


Figure 20: the air pressure system for fuel system

The wide opening throttle (WOT) for the injector is set at 13.25 msec and the amount of the fuel injection is set at 49.70 cc/min. During the measurement of fuel consumption, the engine speed is not accurately at the setup condition for the experiment. The engine speed is not too stable. The unstable engine speed is happen to the both system maybe due to the air intake flow that is not constant. The experiment was conduct at an open air area. If there is too much air being suck by the carburetor, more fuel will be delivered to the intake manifold. For the throttle body injection, although the amount of fuel being inject is constant, but if the amount of air is too much or too less, the wrong mixture fuel air can cause the engine speed not stable.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

As a conclusion, this is only a minor part of the injection system which proof that it can improve the fuel consumption performance. A complex injection system with a lot of sensors that measure such as air speed, air temperature, air pressure, engine speed, throttle opening and etc can improve fuel consumption more efficiently. The objective of this project to improve a fuel consumption of a simple vehicle by using a simple fuel injection was achieved.

For further improvement on the system, more sensors need to be place for the ECU to calculate and provide optimum amount of fuel for the injector to inject and an internal work on the engine at the burn chamber can be considered such as increasing the compression ratio of the engine which also can improve the fuel consumption.

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