CHAPTER 1

INTRODUCTION

1.1 Project Background

A typical gasoline engine will have an average efficiency of 30% when being used to power a car [1]. In other word, almost 70% of the overall energy is ejected as waste in the form of heat and sound throughout the engine component and only around 30% is being used to move the car. Engine efficiency of a spark ignition engine depends on the combustion volumetric efficiency and combustion efficiency [1]. In modern car engine, one of the major technology developments in increasing engine volumetric efficiency is the electronic fuel injection (EFI) system which replaced the used of carburettor as engine fuel delivery system. Electronic fuel injection system improves engine volumetric efficiency by supplying pressurized fuel into the combustion chamber and delivers the fuel with variable feed rate according to the engine load which is controlled by an electronic control unit (ECU) [2]. The other method that is used to increase engine efficiency was turbocharger technology which recycles the waste energy in the exhaust to force fresh air into the intake system [3]. Engine tuning also contributes in increasing engine efficiency. Engine tuning is the adjustment, modification or design of internal combustion engine to yield optimal performance, to increase an engine's power output, economy or durability [1]. Engine tuning process involves improvement activity for example air and fuel ratio process to improves combustion mixture, ignition timing tuning to improves ignition timing for engine combustion and valve timing tuning to increase engine volumetric efficiency during combustion cycle [1]. There are many tuning strategy that can be applied according to the engine suitability. Thus, studies are made to determine the most effective tuning method that will increase the engine efficiency as high as possible. For this project, a single cylinder spark ignition engine has been selected to be tuned to increase efficiency or in other word to reduce the engine fuel consumption to as low as possible.

1.2 Problems Statement

The fuel consumption of an engine can still be optimized by various modifications and tuning of the engine. However, the contribution of these modifications is unique to each engine. Undertaking these modifications and tuning could significantly improve the overall energy conservation of the engine. The modification strategy that was used are using an electronic fuel injection (EFI) system in place of the carburettor, improvement of the engine lubrication system, engine air and fuel ratio improvement, exhaust system modification and ignition system modification.

1.3 Objective

The project main objective is to increase engine performance and to reduce fuel consumption of a single cylinder spark ignition engine by tuning and modification process.

1.4 Scope of Study

The project scope is separated into two main parts accordingly between the first and the second semester. In the first semester, the project focuses on data gathering where basic parameters that are involved in the engine improvement process are determined. The unmodified engine performance was investigated using Dynamometer which could monitor and measure the engine speed, engine torque, and fuel consumption. The unmodified engine then will be documented as a basis for the engine tuning process. The project continues on the second semester where engine tuning process is executed. During the tuning process, theory and knowledge about increasing engine performance is applied to the engine and this involves lots of hands on work. The engine is tuned accordingly based on the tuning method selected and at the end of the each tuning process the engine performance is measured and the results are compared with the unmodified engine performance. Based from the comparison data, the results are then analyzed and discuss in term of achieving the main objectives.

1.5 Relevancy of the Project

This project is relevant to Mechanical Engineering academic syllabus of Universiti Teknologi PETRONAS (UTP). It incorporates knowledge in mechanical engineering design, manufacturing technology, engineering materials, and automotive knowledge especially engine engineering design that is closely related to the project. In addition, it also enhances project management and communication skills.

1.6 Feasibility of the Project within the Scope and Time Frame

For this project, the first semester will cover formulation of methodology and conceptualization of design. The second semester will be concentrated on hands on activities and engine testing to plot the result of the studies. Based on the draft methodology, the project's objectives are considered achievable within the given time frame.

CHAPTER 2

LITERATURE REVIEW

2.1 Engine Optimization Strategy

Engine optimization strategy planning is essential in achieving the project goal. With proper strategies planning, the project progression is more structured and more manageable. One of the best methods in planning excellent strategy is by improvising the strategy used by previous related projects that had succeeded in achieving their objectives. From the information gathered the engine optimization strategies that were implemented by other related project are:

1. Fitting EFI system
2. Lubrication system modification
3. Air fuel ratio tuning
4. Exhaust system modification
5. Ignition system modification

2.2 University of California, Berkeley Supermileage Car

Based on the report done by University of California, Berkeley supermileage car team, the main strategy used as their engine optimization was fitting the engine with and EFI system as shown in Figure 2.1 in place of the carburettor as the intake system in their previous 2006 engine version [1]. List below are the components that had been used in developing the EFI system.

- Fuel injector : Flow rate of 33 cc/min at 35 psi
- Fuel pump : Using pressurized tank connected to the fuel line
- Fuel Regulator : Using aftermarket fuel regulator for car
- ECU : Custom ECU using Luminary Micro LM3S8962 Evaluation Board, the logic control being develop by the student using TIP120 transistor

- Wiring harness : Develop by the students
- Various sensors :
  - MPX4250AP Absolute Pressure sensor
  - LM35 Centigrade temperature sensor
  - Standard narrowband heated oxygen sensor
  - Bosch Coil
  - Hall effect sensor

In 2009the team managed to install a fully customized EFI system and as a result they succeeded to reduce the engine fuel consumption about 30% to 40% of the standard engine fuel consumption and win a supermileage competition organized by Shell in Europe continent. The car they produce manage to travel more than 3000 km with one (1) litre of fuel

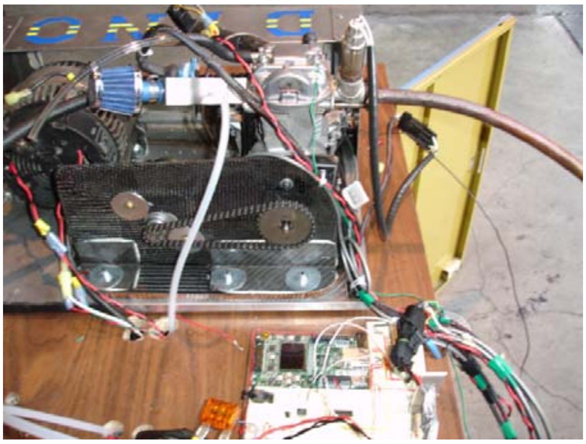

Figure 2.1: University of California supermileage car EFI system

Another engine optimization strategy used by University of California, Berkeley supermileage team is improvement on the lubrication system by upgrading from the standard oil mist delivery system to a pressurized oil delivery system as shown in Figure 2.2 [4]. The benefit of lubrication system improvement is reduction of engine frictional lost thus reducing the work needed to move the piston and other engine moving component and these results in increasing the engine efficiency and reducing the fuel consumption [5].

Figure 2.2: University of California supermileage oil pump system

To increase ignition system efficiency, the standard coil discharger ignition (CDI) was replaced with a more advance electronic coil. With the new ignition coil, greater spark was produce and increases the engine combustion efficiency by reducing the unburned fuel [4].

Figure 2.3: University of California supermileage spark coil

2.3 Fancy Carol-NOK Supermileage Team

In Japan, Fancy Carol-NOK supermileage team increased their engine compression ratio as their optimization strategy [6]. The car designer, Mr. Hisanori said that with increasing of engine compression ratio, the engine will generate more power due to higher volumetric efficiency. The Fancy Carol supermileage manage to set the new supermileage world record with the distance of 4079.1 km for one (1) litre of fuel during supermileage competition held by Shell on the track alongside the Grampian Transportation Museum, North East of Scotland [6].

2.4 NGK Spark Plug CO. LTD

Figure 2.4: Iridium spark plug

Research done by NGK, one of the most successful spark plug manufacturers showed that by replacing the commercial sparkplug with high performance Iridium spark plug it will increase the engine performance and reduce the engine fuel consumption. High performance Iridium plug could improve more than 8 horsepower on various engines [7]. Previously, Platinum was used in spark plug because is more durable, however Iridium is 8 times stronger, 4 times harder and it has a melting point of 1200 degrees and this quality put it surpass Platinum spark plug and the commercial spark plug [7]. The smaller the size of Iridium electrode with the tapered ground electrode, allows more room to flames for producing more efficient combustion and by using Iridium spark plug the life span can last up to 120,000 miles. Most of major automobile companies such as Lexus and Toyota are using this technology in their new vehicle model [7].

2.5 Isfahan University of Technology, Iran

They manage to install EFI system on Honda GX35 that having 35cc displacement. The engine also is a 4-stroke engine and comes standard with carburetor intake module. By installing EFI, they manage to increase the engine power from 1.3 horse power to 2 horsepower at 7000 rpm. Furthermore EFI system also improves the engine standard torque from 1.6 N.m to 2 N.m. The engine is analyzed by using GT Suite software [8].

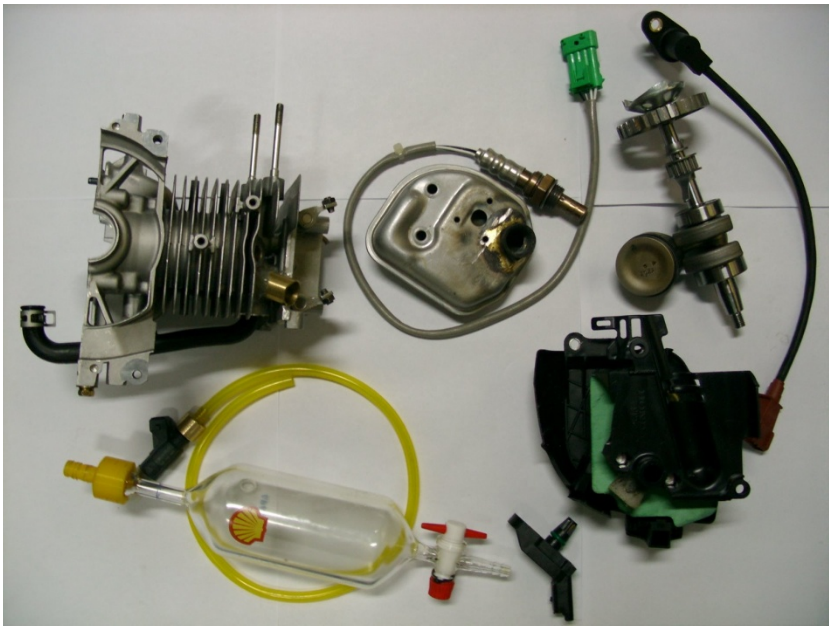

Figure 2.5: Isfahan University of Technology, Iran direct injection system

2.6 Dalhousie University, Canada

In order to compile with Shell regulations, while still maintaining the required pressure to deliver fuel to the injection assembly, Dalhousie team has decided to modify the vehicles current fuel system to use pressurized air to feed the engine with fuel. The setup will use a small, translucent compressed air bottle to pressurize the fuel tank, which will force fuel to the engine while maintaining the required pressure. The main advantage that this system gives us is to maximize the engine assembly efficiency. Shell regulations only allow pressurizing the air tank before completing track runs; the system will not be drawing any energy from the engine to pump the fuel, unlike running a mechanical fuel pump, which requires engine power. The maximum air tank pressure is set by Shell to be 72 psi; this is sufficient to maintain a constant pressure of 40 psi in the system for the duration of each run. The fuel tank required for the Shell competition must also be certified to 72 psi. The set up also offers advantages over the fuel system currently in place where an alternator is required to generate the power used by the electric fuel pump. However, since SAE provides the fuel tank in their competition, and no changes acceptable, they converted the fuel system back to non-pressurized setup for the SAE competition [9].

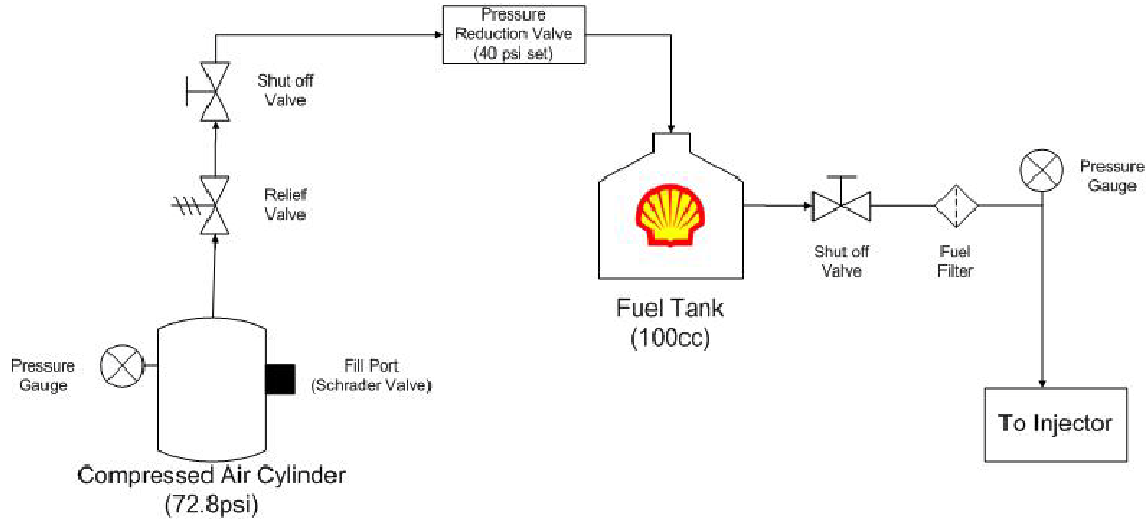

Figure 2.6: Dalhousie University fuel system layout

By using mathematical equations, the team managed to obtain the ideal length of the exhaust pipe in order to get the optimum output of the engine. The length is taken calculated for design at 6000 rpm because the engine has a better mileage on this speed. The exhaust fabricated is as shown in Figure 2.7 [9].

Figure 2.7: Dalhousie University exhaust setup

CHAPTER 3

METHODOLOGY

In the initial stage, the study is focus in learning standard characteristics of the engine. Engine testing is executed in order to determine the engine performance also to obtain information such as the engine fuel consumption, torque and power generated. The testing condition is manipulated using different type of fuel, speed and load in order to obtain the engine performance pattern. Modification on the engine is focusing in the area that is critical from the information that being obtained earlier. A apart from engine component modification, tuning process also took place to fine tuned the engine cycle to achieve it optimum performance.. Studies are made to determine the parameter that will significantly affect the performance of the engine. After all tuning and modification process is complete, the engine will be test again and the result will be compare with standard performance.

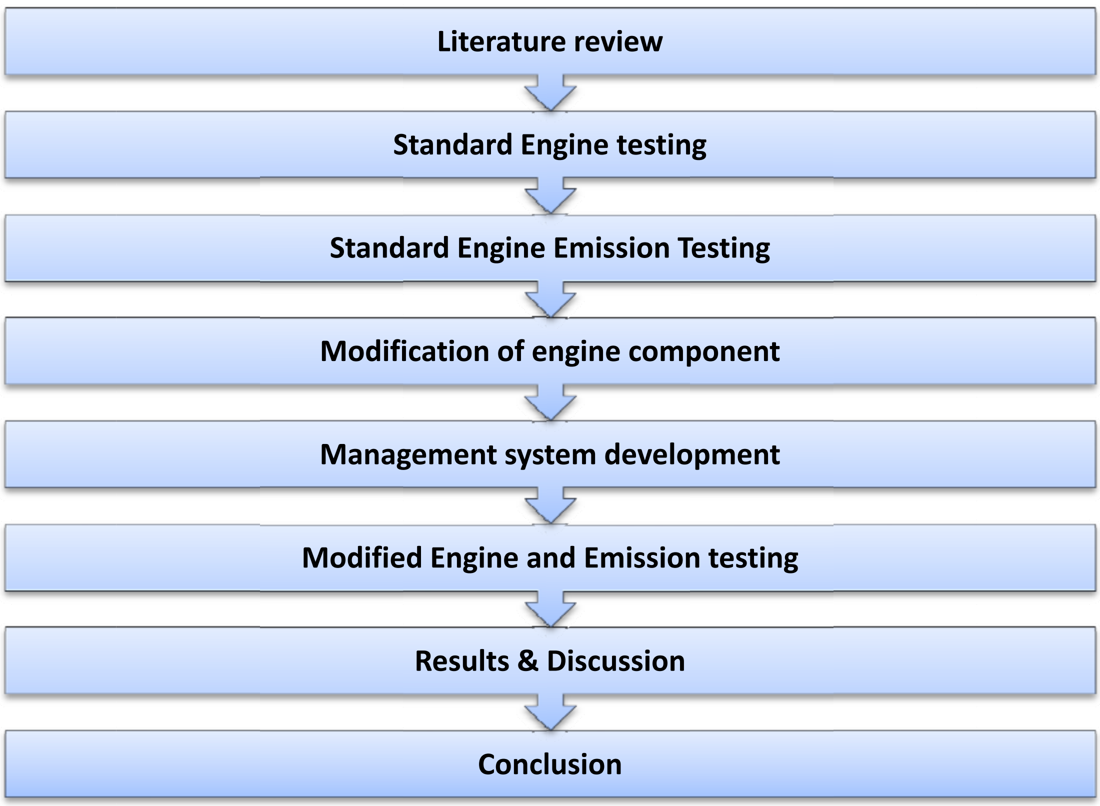

Figure 3.1: Process flow chart

3.1 Engine Testing Setup

3.1.1 Engine Performance Testing

Figure 3.2: TD110-115 Mini Engine test bed

Engine testing has been conducted using TD110-115 mini test bed situated in Block 15. The machine could monitor engine speed, engine torque, exhaust temperature, intake flow and fuel consumption. However the test bed facility is not suitable for Honda GX35 due to its size. To mount the engine, a new engine mounting has been fabricated using aluminium. But the disadvantages using aluminium is the material is not stiff enough to handle the vibration produced by the engine. To address the problem, ribs are added to the engine mounting structure to increase its rigidity. For troubleshooting purposes, several dry runs were conducted to ensure the mounting is safe for the engine testing. During the first dry run of the test observation found that the engine clutch slip due to overloading. From the inspection done, it shows that the clutch friction contact is insufficient to handle the load given for the engine testing. Modification then was made to the clutch to increase the friction at the contact surface by grinding slots on the clutch to the disc surface. With the modified clutch installed it gives better result compared to previous condition where the engine could be test on higher level of load than before.

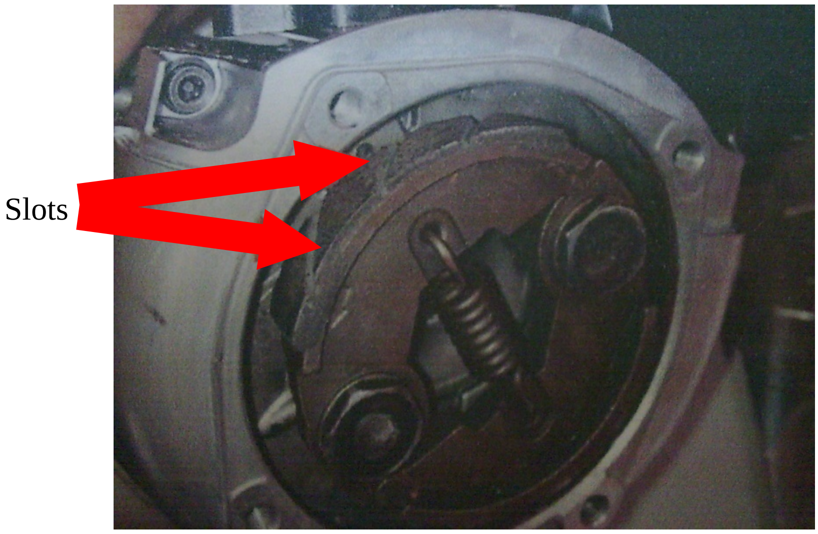

Figure 3.3: Modified centrifugal clutch

Another problem has been spotted after continuing several trials. There was huge power lost at the clutch when operating the engine at high engine speed. Decision was made to remove the clutch and replace it with a coupling shaft that connects the engine output directly to the engine test bed. The shaft was fabricated using mild steel rod and was machined using conventional lathe and milling machine. Precision is important to fabricate the shaft because it will affect the balancing of the rotating shaft. Vibration need to be avoided during the engine testing in order to ensure human safety and the safety of the machined. Thus during the fabrication process the shaft was carefully measured using coordinated measuring machine (CMM) to ensure the precision of the shaft dimension and centricity as shown in Figure 3.4. With the replacement of the clutch with the shaft, the slip problem has been resolved.

Figure 3.4: Coordinate measuring machine

3.1.2 Fuel Consumption Testing Setup

The fuel consumption of the engine was determined in term of mile per gallon (MPG) under specific engine loading. The MPG was obtained by measuring the mass of fuel used by the engine to move the chassis to a certain distance. The engine is mounted on a tricycle that having an overall weight of 140 kg including the mass of the driver. The testing is conducted using a track with the distance cover is 3 km.

3.2 Engine Testing Procedure

3.2.1 Engine Performance Testing Procedure

Initially, the engine being throttled to reach its maximum engine speed possible. After the maximum speed was reached, load then was applied to the engine. Increment of the load continues from the maximum engine speed until it decreased to a critical engine speed. Critical engine speed is the lowest limit of engine speed before the engine decelerates to a sudden stop due to overloading. The critical speed sets for the experiment is at 2000 rpm. During the engine testing the engine torque was monitored as shown in Figure 3.5. The maximum torque is taken when at the critical engine speed. The experiment was repeated by manipulating the engine speed start point from 6000 rpm to 3000 rpm.

Figure 3.5: Monitoring the engine torque

3.2.2 Fuel Consumption Testing Procedure

The first step of the testing is to empty the fuel tank and the remaining fuel in the engine. Then 50 ml of fuel is filled into the tank. Later on, the vehicle were the engine is mounted is being droved at constant speed of 35 km/h through the track until it reaches the desired distance. The engine then being stop and the remaining fuel is measured. To calculate the MPG, the differences between the initial fuel volume and the final volume is divided by the total distance travel as shown in Equation 3.1.

MPG = total distance travel (mile) / total fuel used (gallon)   (3.1)

3.3 Equipment Used

3.3.1 Dynamometer

The testing conducted using dynamometer to determine the torque and power required to operate a driven machine such as pump. In that case, motoring or driving dynamometer is used as shown in Figure 3.6.

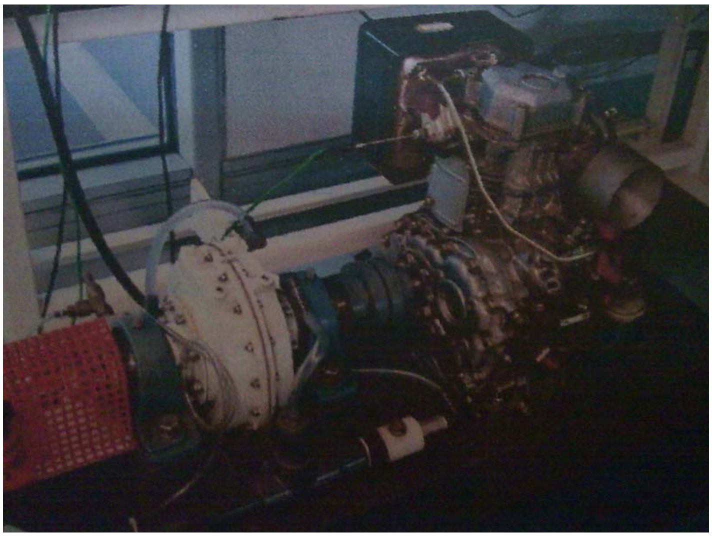

Figure 3.6: Single cylinder engine dynamometer

The main engine performance parameter that is being observed is the engine torque and the engine fuel consumption. Initially, the engine will be test with its default condition and the result is taken as based line reading and to be compared with the result of the engine after modification. The main parameter concern from the expected result must shows that the fuel consumption should be reduced after optimization.

3.3.2 Gas Analyzer

Basically this test concerning the level of oxygen produced by the exhaust fumed. Wideband analyzer as shown in Figure 3.7 will be used to monitor the oxygen level by detecting the presence of oxygen in the exhaust emission by using a lambda sensor.

Figure 3.7: Wideband gas analyzer

From the reading, it will determine the Air Fuel Ratio (AFR) of the combustion occur in the engine. Any mixture less than 14.7:1 is considered to be rich mixture, and any mixture more than 14.7:1 is considered to be lean mixture. The present of oxygen in the exhaust fume shows that the engine is having lean mixture meaning the mixture having low level of fuel, opposite with rich mixture condition less present of oxygen could be observe. The oxygen level is sense by using Lambda Sensor that produce small voltage resistance in presents of oxygen. Usually for rich mixture, the range of voltage produce is from 0.6 Volt to 1 Volt and for lean mixture, the reading varies from 0 Volt to 0.3 Volt. The ranged of voltage that correspond the certain level of air fuel ratio varies according to the device manufacturer. For the wideband analyzer being used, if the voltage reads 1 Volt, it will correspond to AFR=10:1. With the information obtained by the system, optimization could be made to fine tuned the AFR closed to the ideal AFR=14.7.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Unmodified Engine Performance Test Result

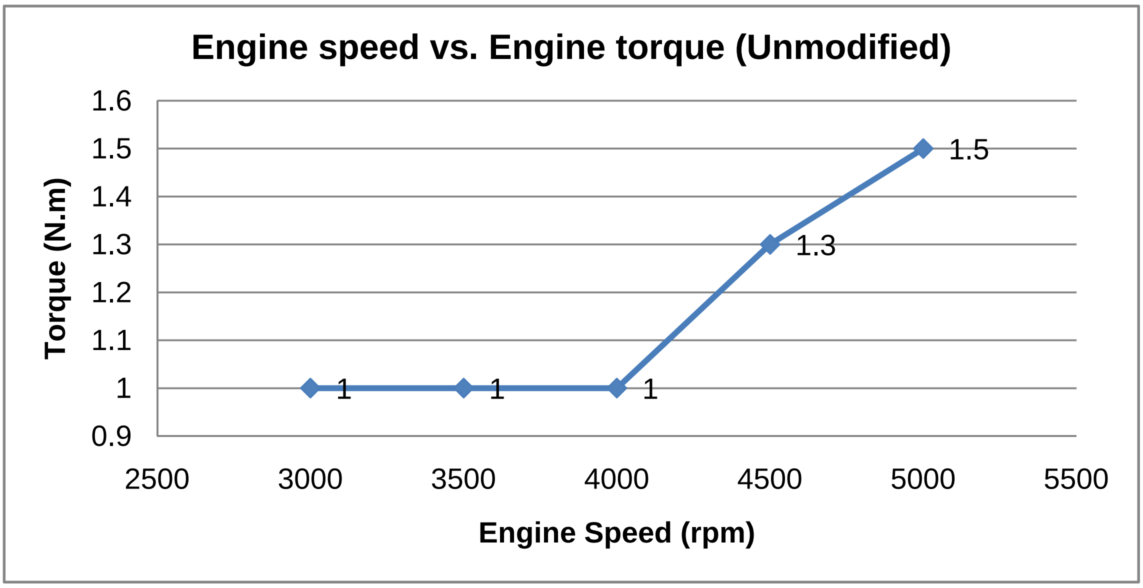

Figure 4.1: Unmodified engine speed vs. engine torque

Based from the result in Figure 4.1, noted that the reading is measured from 3000 rpm. This is because it is the lowest rpm possible to measure the torque due to engine vibration. The highest torque produce by the engine occur at 5000 rpm and this is undesirable because the engine speed is very high and will produce high frequency of vibration and could shorten the engine durability. Thus improvements are made to increase the torque at lower engine speed range from 3000 rpm to 4000 rpm.

4.2 Unmodified Engine Fuel Consumption Test Result

Table 4.1: Engine fuel consumption test result

No. of Test	Distance travel (km)	Initial Fuel volume (ml)	Final Fuel Volume (ml)	Fuel Usage (ml)	MPG
1	3	50	44.3	5.7	1242.7
2	3	50	46.2	3.8	1864
3	3	50	42.6	7.4	981.1
				Average	**1362.6**

4.3 Engine Improvement and Modification

4.3.1 Fitting Electronic Fuel Injection (EFI) System

The EFI that was used is specially design for small engine complete with a throttle positioning sensor and optical pick up sensor that was ordered directly from Japan as shown in figure 4.2. To fit the EFI system to the engine, some modification and fabrication needed for the EFI intake manifold and sensors mounting. A new intake manifold mounting was fabricated using aluminium because aluminium is known for its low density and it is easy to be machined. The engine port needs to be bore to suite the EFI intake manifold runner diameter to clear any restriction that could results in pressure drop for the intake flow rate. The injector angle, is properly align so that during injection, the injector tip is properly directed to the valve opening area in order to optimized the volume of fuel entering the combustion chamber. The EFI system uses an optical pick up sensor to determine the timing of injection correspond to the engine cycle. The pickup sensor comes with a disk that having a notch to denoted the injection timing. The disk was attached to the crank shaft and the notch was position at 15 degree before the piston top dead centre (TDC) position. In other word the injection will occur before the piston reach the maximum altitude.

Figure 4.2: FC Design fuel injection system

Due to facilities availability and time constrain, the performance of engine with EFI being fitted could not be analyzed by using the dynamometer. However the performance was measure by using simulation software (GT-Power) that could replicate the testing procedure and condition and giving similar result as using measurement using dynamometer. As precaution, a simulation being done to replicate the testing condition of the unmodified engine. From the simulation it produces that same reading as being measured by the dynamometer thus show that the measurement using the software is eligible. GT-Power is simulation software which helps to analyze engine performance by only inputting the engine critical design dimension. The software is rapidly used by engine manufacturer to reduce engine development duration and cost. To analyze the engine that have been fitted with EFI, the engine model in the software have been replicated with the same attributed as the real engine and the result is as shown in figure 4.3.

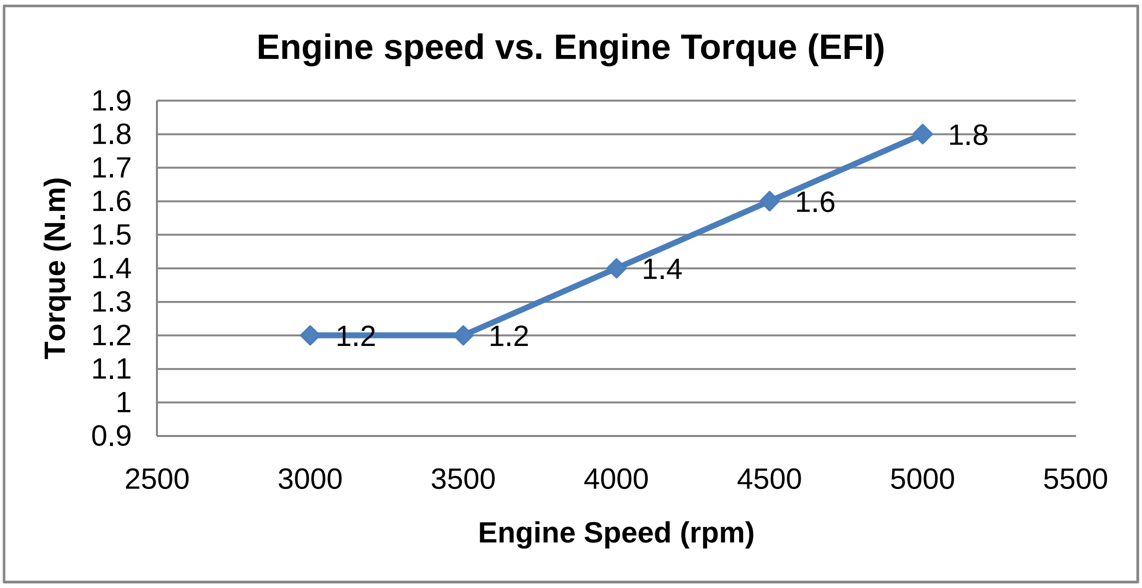

Figure 4.3: Engine with EFI engine speed vs. engine torque

Table 4.2: Engine with EFI fuel consumption test result

No. of Test	Distance travel (km)	Initial Fuel volume (ml)	Final Fuel Volume (ml)	Fuel Usage (ml)	MPG
1	3	50	47.2	3.8	1864.0
2	3	50	45.5	4.5	1553.3
3	3	50	46.3	3.7	2071.1
				Average	**1829.5**

4.3.2 Air and Fuel Ratio Tuning

Tuning AFR is crucial in adjusting the ratio between the mass of fuel and air that enter the combustion chamber. The tuning process main objective is to fine tune the mass of fuel supplied as low as possible without ignoring the engine performance aspect. However the fuel requirement for combustion of an engine varies with the engine loading. At low engine speed less fuel is needed thus required leaner mixture and at higher engine speed higher volume of fuel is required thus richer mixture is needed. AFR tuning requires measuring equipment such as wideband analyzer to measure the level of oxygen in the emission. The oxygen level was measure using a lambda sensor which detect the presence of oxygen and register different voltage reading according to the oxygen concentration. The sensor is place in the exhaust system and will register the emission air fuel ratio while the engine is operating.

To tune the AFR, the mass of fuel feed to the engine is manipulated until the wideband register the AFR closed to the ideal AFR. The mass of fuel supplied to the engine can be controlled by varying the dwell time of the injector. To have lean mixture, the injector will open and close quicker than the normal rate and to have a rich mixture, the injector will open and close slower than the normal rate. Thus in reducing the engine fuel consumption, the AFR is increase to have a leaner mixture than the unmodified engine AFR. However, by varying the AFR, it will affect the engine performance significantly. Based on the engine simulation test result as shown in Figure 4.4, it shows that with increasing of AFR, it will decrease the engine torque. From several manipulation done, the best air and fuel ratio is at AFR=15:1 where the engine torque is similar to the unmodified engine torque by using lesser amount of fuel due to having higher AFR.

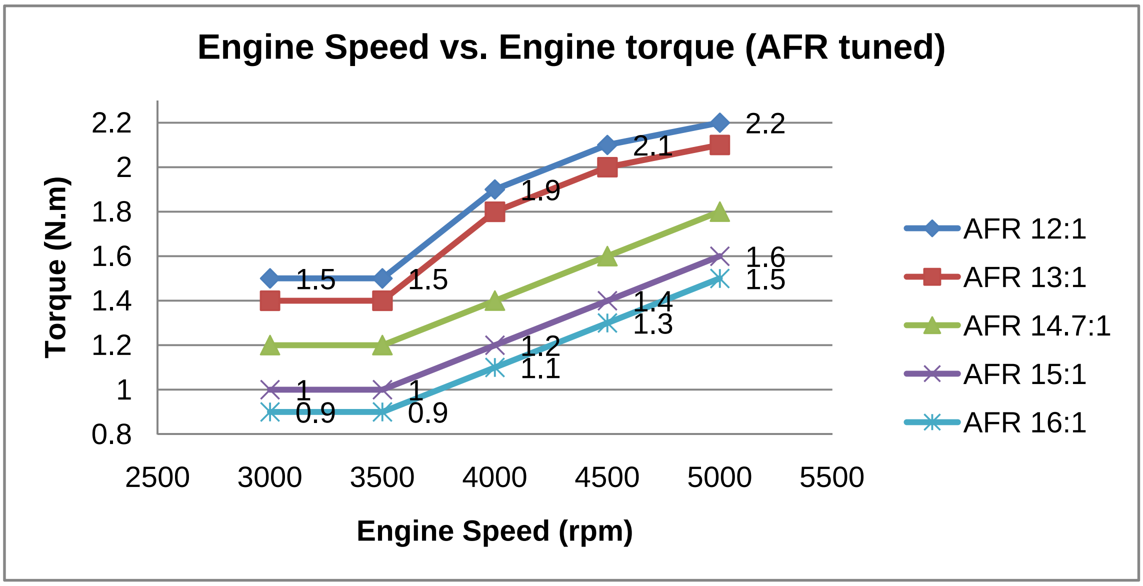

Figure 4.4: Engine with tuned AFR engine speed vs. engine torque

4.3.3 Exhaust Modification

The calculation for exhaust length dependent on engine speed and gas flow temperature. Thus, the engine can only be tune for one specific engine speed unless variable length of exhaust is used. Design for Honda GX35 was difficult because the engine design to run over board engine speed range. Therefore for the calculation, engine speed at 6000 rpm is chosen. This is because the engine optimum volumetric efficiency operates at wide open throttle (WOT) range from 5000 rpm to 6000 rpm. The temperature reach a maximum of 291 degree Celsius and this gave the exhaust length of 0.793 m.

When the exhaust valve opens, a compression wave is sent downstream and reflects back as a rarefaction wave when an opening in the exhaust system is encountered. Experimentally it has been found that the optimum position of the piston when the wave returns is 120^{o}. The required length of the exhaust pipe can then be determined.

Exhaust Timing $$time = \frac{\theta}{\dot{\theta}} = \frac{120^{o}}{RPM\left(\frac{360}{60}\right)} = \frac{20}{RPM} \quad (4.1)$$

Exhaust length $$L = \frac{10c}{RPM} \quad (4.2)$$

Speed of sound at specific temperature $$c = (kRT)^{\frac{1}{2}} \quad (4.3)$$

Where,

k = specific heat ratio

R = air ideal gas constant

T = temperature (in Kelvin) of the flow

However, the actual length could not be determined due to availability issue of the Dynamometer. The result will be updated in the next progress report.

4.3.4 Lubrication System Optimization

Lubrication system improvement involves the process of choosing the best lubricant oil that is available in the commercial market. Different type of viscosity of lubricant gives different range of performance for the engine. To reduce the engine fuel consumption the desired lubricant should help reduce the frictional loss and remove heat efficiently from the engine component surface. Test was done for several type of engine oil as shown in Table 4.3 and the result shows that by using fully synthetic engine oil the engine achieve the best performance compared using other type of engine oil.

Table 4.3: Lubrication improvement test result

Type of engine oil	Engine torque at 5000 rpm (N.m)	Engine fuel consumption (MPG)
Low grade motorcycle engine oil	1.6	1252.3
High grade motorcycle oil	1.6	1252.3
Semi-synthetic car engine oil	1.7	1489.8
Fully-synthetic car engine oil	1.9	1856.2

The differences between motorcycle engine oil and car engine oil is on the oil compound itself. Motorcycle engine oil compound is specifically design for higher anti ware additives (phosphorous) because motorcycle engine oil also using the same lubricant to lubricate the transmission. Thus with this extra compound reduce the engine oil performance in providing low friction surface. For car engine oil is specially design to provide as minimum friction in order to reduce fuel consumption. Thus for the engine that is used for the project, car engine oil is the most suitable type and helps in increasing the engine efficiency.

4.4 Modified Engine Performance and Fuel Consumption

The main objective of this final engine testing is to measure and compare the current engine performance with the unmodified engine performance. This is to prove that improvement done on the engine helps in increasing engine performance and reduce the engine fuel consumption. The differences between the modified and unmodified engine specification are shown in Table 4.4.

Table 4.4: Engine specification comparison

Engine specification	**Engine condition**	
	Unmodified (before)	Modified (after)
Fuel system	Carburettor	EFI
Air fuel ratio	12:1	15:1
Engine oil	Motorcycle oil	Fully-synthetic car engine oil

4.4.1 Modified Engine Performance Test Result

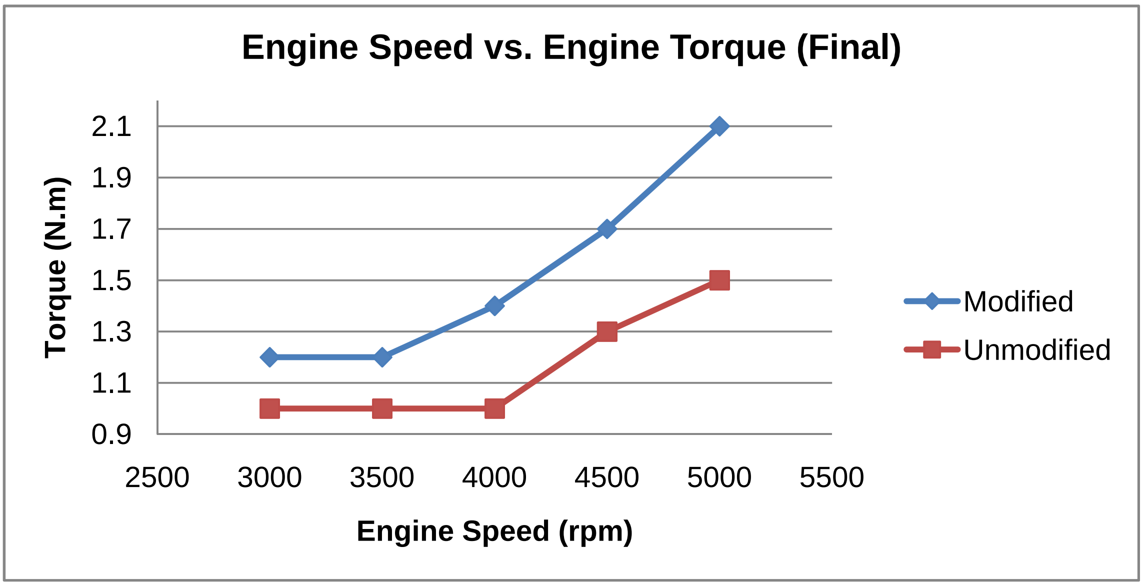

Figure 4.5: Comparison between modified and unmodified engine performane

Based on Figure 4.5, it can be seen that the modified engine have higher torque than the unmodified engine. In other word, the improvement and modification made to the engine has successfully improved the engine performance where the maximum torque produce by the modified engine reach up to 2.1 N.m compared to the unmodified engine torque that only producing up to 1.5 N.m. Furthermore, the results also shows significant improvement on the engine torque curve where the engine produces higer torque at lower engine speed. The modified engine torque show improvement at 3000 rpm where the torque start to increase proportionally with the increase of engine speed. This is different with the unmodified engine torque curve where the torque only increases late after at 4000 rpm.

4.4.2 Modified Engine Fuel Consumption Test Result

Table 4.5: Modified engine fuel consumption test result

No. of Test	Distance travel (km)	Initial Fuel volume (ml)	Final Fuel Volume (ml)	Fuel Usage (ml)	MPG
1	3	50	47.4	2.6	2741.2
2	3	50	47.3	2.7	2662.9
3	3	50	47.3	2.7	2662.9
				Average	**2689.0**

A part from having improvement on the engine performance, it is also shown that, the modified engine has drastically improved its MPG. The modified engine achieved higher mileage of 2662.9 mpg than the unmodified engine mileage 1242.7 mpg. This shows that the engine fuel consumption value has been reduced more than twice from the original fuel consumption value.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The result shows that the project has successfully achieved its main objective to improve the engine performance and reduce the engine fuel consumption. One of the main factor contributes to the project achievement was the engine optimization strategy planning done earlier in the project. Fitting and EFI system to the engine provided significant change to the overall engine performance where drastically improve the engine torque and further reduce the engine fuel consumption. An EFI system improves the engine volumetric efficiency which ensures optimum amount of fuel is supplied for combustion. To further reduce the engine fuel consumption, the engine AFR has been tuned to the optimum. It shows that by increasing the AFR, the leaner the air and fuel mixture and this reduce the engine performance gradually. From several testing done, the optimum AFR obtained for the engine is at AFR=15:1 where the engine performance is almost similar to the unmodified engine performance but consume lesser fuel. In term of exhaust system modification, the dimension of the exhaust has been calculated to produce the optimum performance at the designed engine speed. As a conclusion all the improvement performed on the engine have increase the engine performance and reduce the fuel consumption significantly. The engine maximum torque has increased from 1.5 N.m to 2.1 N.m at 5000 rpm and the engine fuel consumption reduce from reduce and produce a better mileage from 1242.8 mpg to 2662.9 mpg.

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APPENDIX 1: FYP 1 Gantt Chart

NO	ACTIVITY	SEMESTER JULY 2009														
		1	2	3	4	5	6	7	8	9	Mid-Semester Break	10	11	12	13	14
1	**Problem Definition**															
	Project Planning															
	Literature Review															
	Concept Desin Review															
	Concept Design Selection															
2	**Engine Testing**															
	Engine Mounting Preparation															
	Standard Engine Testing															
	Analysing Result Data															
3	**Final Year Project**															
	Preliminary Report															
	Progree Report															
	Seminar															
	Interim Report															
	Oral Presenatation															

APPENDIX 1: FYP 2 Gantt Chart

NO	ACTIVITY	SEMESTER JANUARY 2010														
		1	2	3	4	5	6	7	8	9	Mid-Semester Break	10	11	12	13	14
1	**Emission Testing**															
	Engine Preparation	■														
	Standard Engine Emission	■	■													
	Result Analysis			■	■											
2	**Engine Modification**															
	Modification Planning				■											
	Component Preparation				■	■	■									
	Fabrication Process						■	■	■	■						
	Assembly									■		■				
	Pilot Trial											■				
3	**Management System**															
	Component Preparation				■	■										
	Assembly					■	■	■	■							
	Pilot Trial								■	■						
4	**Engine And Emission testing**															
	Engine Mounting Preparation												■			
	Modified Engine testing													■	■	
	Modified eng. Emission Testing													■	■	
	Result Analysis														■	
	Improvement (if required)														■	■