# Optimization of fuel efficiency by installing EFI in a Carburetor Engine.

A Final Year Project Report

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Bachelors of Mechanical Engineering

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# ABSTRACT

The project is based upon conversion of a carburetor engine into an electronic fuel injection system one. This aims to achieve better fuel efficiency and achieve desirable emissions standards which are not possible in using the old carburetor system. The Engine Management Unit (EMU) will be designed and installed to get maximum results. Dyno testing will be done to verify the results and theoretical calculations. The engine is also made to fit to be run in a car, design and fabricated for Shell Eco Marathon competition so that the project also gets practically demonstrated, tested and acknowledged internationally.

The project aims to incorporate technology advancement in order to optimize fuel economy and also to shift towards better environmental practices by taking a wide perspective in view for any engineering design and implementation.

# PREFACE

Our profound knowledge and understanding of rising environmental concerns around the globe and Pakistan nearing towards grave environmental disasters have encouraged us to work in lines of solving and focusing on a most prevailing source of $CO_2$, the IC engines. Our team had planned to participate in Shell Eco-marathon France 2017 and again in Singapore with more optimization and enhancement. This showed near to practical demonstration of our research and work, most importantly mostly deploying resources and expertise locally available. With motivation and aim to enhance fuel efficiency and reduce harmful exhaust gasses from Internal Combustion Engines, a carburetor engine in selected and replaced with an electronic fuel injection system within it to achieve better efficiency and lower emissions.

# ACKNOWLEDGMENTS

We are grateful to our school, faculty and administration to help us with achieving adequate knowledge, exposure and opportunities to make constructive progress towards making ourselves not only better engineers, but better citizens of this country and a resource for people associated to us in any way. In particular,

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***Dr Jawad Aslam*** for helping and teaching us to micro manage our resources and a constant support in our endeavors.

## ORIGINALITY REPORT

ORIGINALITY REPORT

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# ABBREVIATIONS

| | |
|---|---|
| AFR | Air Fuel Ratio |
| VE | Volumetric Efficiency |
| RPM | Revolutions per minute |
| BDC | Bottom Dead Center |
| TDC | Top Dead Center |
| ABDC | After Bottom Dead Center |
| MFR | Mass Flow Rate |
| WOT | Wide Open Throttle |
| MBT | Max. Brake torque |
| EMS | Engine Management System |
| SI | Spark Ignition |
| EFI | Electronic Fuel Injection |
| CR | Compression Ratio |
| TPS | Throttle Position Sensor |
| CKP | Crankshaft Position Sensor |
| BMEP | Brake Mean Effective Pressure |

# NOMENCLATURE

$T_{actual}$ = Actual Torque

$T_{max.}$ = max. Torque

P = Pressure

ρ = Density

V = velocity

$t_{wave}$ = time of wave travelling

L = length of runner

$C_{local}$ = Speed owave

N = number of revolutions

$V_{cyl}$ = Volume of Cylinder

$P_{cc}$ = Pressure of crank case

**$V_s$ =** swept Volume

$V_c$ = Clearance Volume

$P_{cyl}$ = Pressure in cylinder

$F_{roll}$ = rolling resistance

$F_{aero}$ = Aerodynamic drag

$F_{traction}$ = traction Force

# CHAPTER 1: INTRODUCTION

## History and Application of IC Engines

Internal Combustion Engines (ICE) are engines in which fuel is burnt in a confined chamber are one of the most common sources of power for land and water vehicles these days. This exothermic reaction of fuel creates gases of high temperature and pressure which are then permitted to expand. The expansion of these gases performs useful work, which is taken to causes movement for a mechanical operation.

Since their early invention or development in mid-18$^{th}$ century, till present day its development has been shared among various scientists and engineers. Two key factors against which its development is being revolved recently are its Fuel Efficiency and Environmentally friendly exhaust gasses. Numerous techniques and approaches have been tested and adopted to achieve both the previously mentioned objectives.

Problem:

- In order to achieve better fuel efficiency and emission standards. Scientists and industrialists have introduced new fuels that release less harmful gasses to achieve the desire emission standards, like the use of natural gas or alcohol. But there are many constraints to these alternative fuels instead of the more conveniently performed gasoline or diesel. In many countries the access or availability of these fuels are difficult, they might also be scarce in some regions, they may have other more essential uses instead of being burned commercially in engines e.g. the natural gas is domestically used in many countries and also a prime source for energy in fertilizer industries so it's not desirable to be used it in ICE. These constraints have hampered our growth in achieving the set objectives. The most recent commonly used engines are carburetor engines that mechanically injects fuel into the engine. This system has been widely used but now it's been replaced by a better and an efficient EFI system. The carburetor engines have several disadvantages;

- At low speeds the air fuel mixture is weak and doesn't ignite properly hence fuel losses and unburned fuel is fed into the air.
- It is affected by atmospheric changes.
- The engine is designed to give maximum results at a particular engine speed, hence not very feasible with vehicles.
- Higher maintenance cost.
- More emissions and fuel wastage.

Objective

The ideal way to achieve maximum efficiency and achieve emissions standards is to electronically control the fuel injection into the engine for combustion. This could be easily standardized and applied everywhere, with fewer resources and efforts. The idea is to convert a carburetor engine into a fuel injecting one so that maximum optimization in terms of fuel efficiency and suitable emissions could be achieved.

# CHAPTER 2: LITERATURE REVIEW

## Engine Management System: [1] [2] [3]

Engine management systems (EMS) has become an essential component of a spark ignition (SI) engine in order to achieve high performance; low fuel consumption and low exhaust emissions. An engine management system (EMS) is a mixed-signal embedded system interacting with the engine through number of sensors and actuators. In addition, it includes an engine control algorithm in the control unit. The control strategies in EMS are intended for air-to-fuel ratio control, ignition control, electronic throttle control, idle speed control, etc. Hence, the control system architecture of an EMS consists of many sub-control modules in its structural design to provide an effective output from the engine. Superior output from the engine is attained by the effective design and implementation of the control system in EMS.

Components of EMS: [2]

- Actuators
- Sensors
- Controller

## Working:

Engine management system (EMS) usually consists of various sensors to monitor the real-time operating conditions of the engine and actuators to control injector, spark plug, throttle, etc. The control signal sent to different actuators is accomplished by means of the EMS control system, which is comprised of a large number of control modules (control loops) in its architecture. The schematic representation of the control system architecture of SI engine is shown in Fig. 1. Some of the basic modules within the EMS which are coordinated with the torque control module are, 1) air–fuel ratio (AFR) control; 2) electronic throttle control (ETC); 3) idle speed control; 4) ignition timing control; 5) knock control; 6) diagnostics control,

The control functions are managed by software control algorithms in the EMS. The design and implementation of control algorithms is a crucial element in the development of automotive engine-control systems because of different operating modes of engines such as: the start-up mode, idling mode, normal operation mode, high power output mode, etc. Once the engine is started, the EMS must make a judgment about the engine operating conditions according to the data collected by different sensors. Through this process the EMS calculates and adjusts the injection time, ignition advance, throttle angle, etc. by the respective actuators [5]. The engine management system (EMS) coordinates with other vehicle control systems (cruise con- trol, ABS, ESP, etc.) for enhanced vehicle performance and handling.

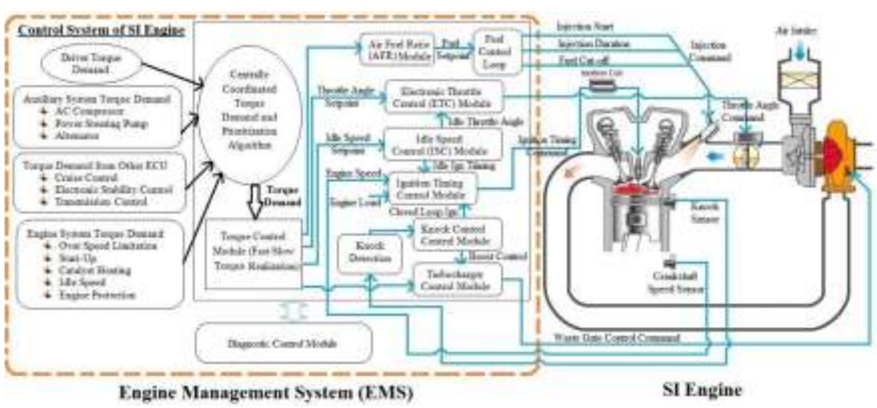


Figure 1 EMS

**Tuning Approaches: [6]**

There are majorly two approaches to tune an engine:

- Tuning for AFR (Speed Density – Volumetric Efficiency)
- Tuning for maximum Torque (Alpha N - Percentage load)

Engine is mounted on engine Dynamometer [7], and load is applied. Now, both approaches depend on data from different sensors with respect to RPM. Dyno tells about the AFR, Volumetric Efficiency, torque and Power based on Rpm and changing load.

- Speed Density – Volumetric Efficiency

  The engine is tuned on the basis of AFR as illustrated by the λ sensor, λ sensor tells the amount of $O_2$ in exhaust, therefore showing the AFR value. We have to achieve the peak torque with the value of Sensor around 1.0 in order to maximize the fuel efficiency. For this purpose, AFR has to be lean which means that mass of air entering should be more than stoichiometric AFR of 14.7. on a specific load, AFR and Volumetric Efficiency given by the Dyno based on the data of Map Sensor (manifold air pressure) and its relation with the rpm, VE is decreased so that Fuel injected by the injectors also decreases whereas the same amount of air is sucked in, hence increasing the AFR, making the mixture lean.

- Alpha-N – (percentage load)

Alpha – N is the approach to tune the engine in which data from TPS is collected and compared with the rpm of the engine. The goal is to calculate the percentage load which the ratio of actual torque over Rpm to max. torque over rpm. $T_{max}$ is obtained by wide opening the throttle on the rpm.

**Factors affecting Volumetric efficiency: [8]**

By definition, volumetric efficiency is defined as the ratio of *mass* of the air / fuel charge ingested by the engine to the product of swept volume and density of air at ambient conditions. Percentage;

$$\eta_v = \frac{m_{ch}}{\rho_{ch,atm} \cdot V_s} = \frac{\rho_{ch,cyl} \cdot V_{s,cyl}}{\rho_{ch,atm} \cdot V_s} = \frac{\frac{P_{cy}l}{T_{cyl}}}{\frac{P_{atm}}{T_{atm}}} \left( \frac{V_{s,cyl}}{V_s} \right)$$

Factors Affecting the VE:

1. **Compression Ratio:**

The higher the compression ratio, the more the air gets compressed in the cylinder and we get the powerful explosion from the air fuel mixture in the cylinder thus increasing the efficiency of the engine. But the compression ratio is restricted by the knocking. So CR can’t exceed from a specific value otherwise it would result in knocking.

2. **Surface to Volume ration:**

The more the S/V ratio, the more the heat loss from the cylinder hence decreasing the efficiency of the engine. The engine with the S/V value of the cylinder close to sphere is best fit to control the loss of heat from cylinder hence increasing the efficiency.

3. **Fuel evaporation**

   Fuel Evaporation will always be less than 100% for naturally-aspirated SI engines (no turbo / supercharging). As the injected fuel is sprayed into the manifold, it evaporates, taking place of the intake air. If fuel is injected earlier, more fuel evaporates and takes space of the air charge, and thus it reduces the VE. So the timing the of the fuel restricts the fuel to evaporate and enables it to burn at right time for combustion, hence increasing the VE.

4. **Fluid Friction:**

   Air flows through a duct with bends, changing radii, filter, throttle valve and intake valve. Fluid (air) flowing through any duct will experience a pressure drop. For a naturally aspirated engine, the cylinder pressure is thus always lower than atmospheric. Fluid friction is more significant at high flow velocity rates. VE will

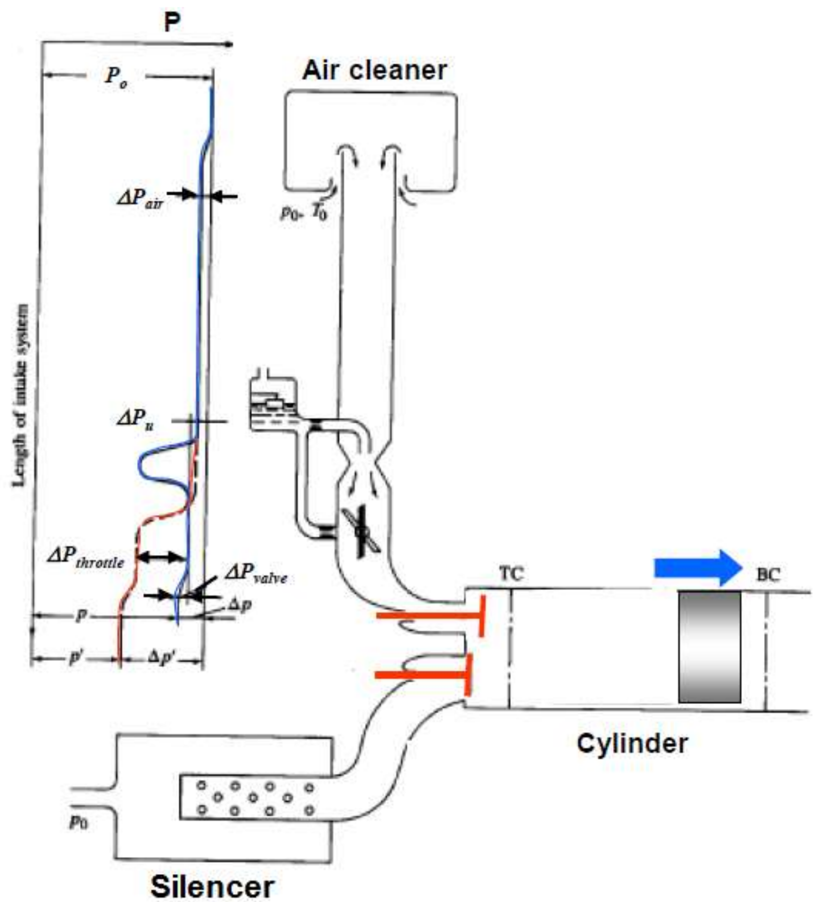


Figure 2 Fluid Friction losses

**5. Opening intake before TDC on exhaust stroke (overlap)**

In real engines, to ensure that the valve is fully open during a stroke (and ensure a $\eta_v$), the valves are open for more than 180°. The exhaust valve opens before BDC and closes after TDC. The intake valve opens before TDC and closes after BDC. At TDC there is valve overlap where both intake and exhaust valves are open. The longer the valve overlap, the more the exhaust gases will rush into the intake manifold at each intake process. Most problematic at idle (part throttle and lower engine speeds) – low intake pressure and more time for exhaust gases to back up into intake.

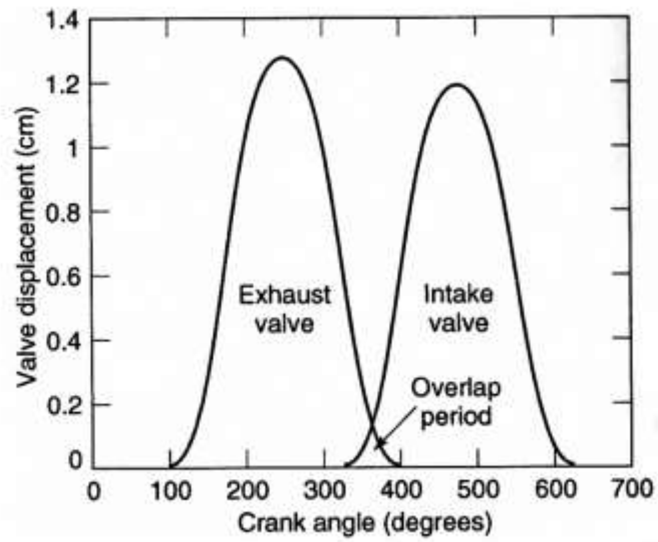


Figure 3 Valve Overlap

**6. Closing intake after BDC on compression stroke (backflow)**

Due to partial vacuum, AF mixture continues to flow into the cylinder even ABDC. As long as $\Delta P > 0$, we can keep valve open. Best time is to close intake valve when intake and cylinder pressures are equal if timing is too late then it would result in backflow; if it is too early then it will result insufficient charging. At high engine speeds, the $\Delta P$ increases, we can wait till much later than at low engine speed to close the intake valve (~60° ABDC). At low engine speeds, the $\Delta P$ decreases, so we have to close intake valve earlier than at high speed (~40° ABDC)

7. **Ram Effect:**

At high engine speeds, as the intake valve closes, the inertia of air in the intake increases the pressure in the intake port.

$$P + \rho v^2 = const$$

Thus allowing more air to be ingested by the engine. This effect becomes progressively more significant at higher engine speeds hence increasing the VE. To take advantage of the ram effect, the intake valve is closed ABDC.

**Intake tuning**

Upon opening of the intake valve, air suddenly rushes into the cylinder. This causes the generation of an expansion wave which propagates back into the intake manifold at the local sonic speed. When the expansion wave reaches the end of the intake runner, it reflects back to the intake valve as a compression wave. The time taken for the round trip depends on the length of the runner and the flow velocity. If the wave is timed correctly, it will arrive back at the intake at the end of the intake process raising the intake pressure allowing more air charge to be taken in by the engine.

$$t_{wave} = \frac{2L}{c_{local}} \qquad t_{valve} \approx \frac{1/3}{N} \qquad L \approx \frac{c_{local}}{6N}$$

**8. Choking**

At very high piston speeds, the velocity at the point where the flow area in the port and the valve is minimum can become sonic. This limits the MFR hence decreasing the VE.

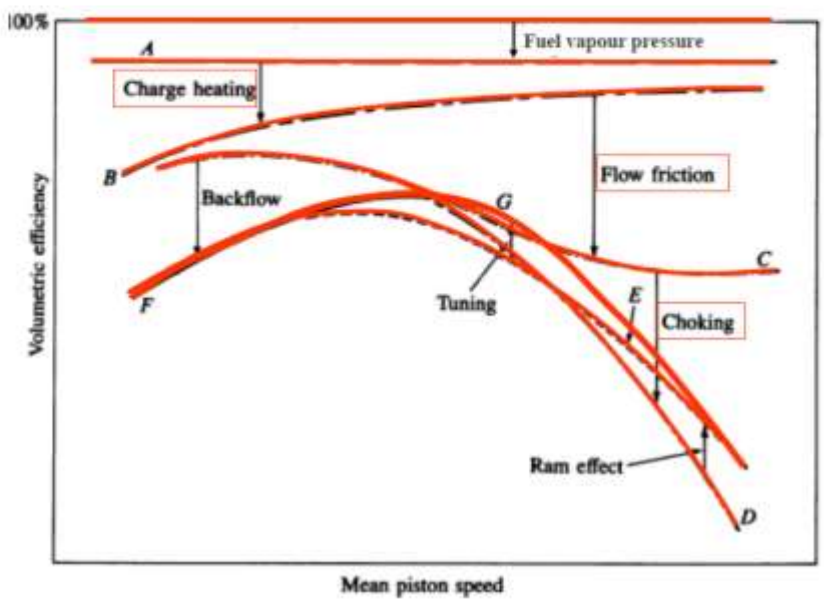


Figure 4 Factors Affecting VE

Hence from figure it can be seen that Fuel Evaporation remains constant with the increasing Piston speed. But all other factors affect the VE in different ways. Ram effect and Tuning increase the VE and all the other factors have adverse effect on VE which should be resolved in order to increase the fuel efficiency.

**Knocking: [8]**

The phenomenon which affects the efficiency as well as performance of the engine is Knocking. **Knock** is the general term used to describe a pinging noise that is emitted by an SI engine if it is undergoing abnormal combustion

The noise is generated by shock waves produced in the combustion chamber / cylinder as a result of this abnormal combustion.’

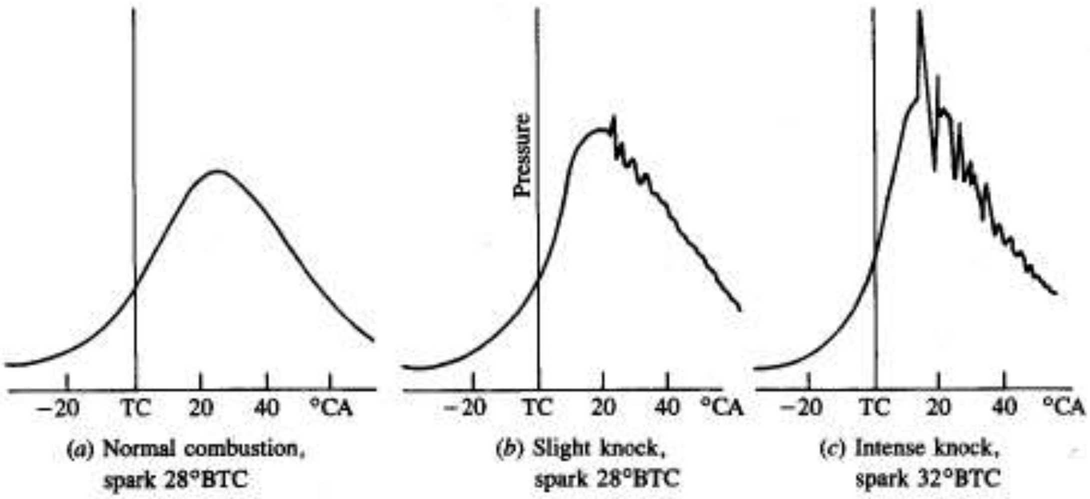


Figure 5 Retardation effect on Knocking

**Knocking** can quickly damage an engine. Damage is due to a combination of high pressure and high temperature. Knock at low load may be less damaging than knock at full or high load conditions. Piston ring lands, head gaskets, cylinder heads are usually affected.

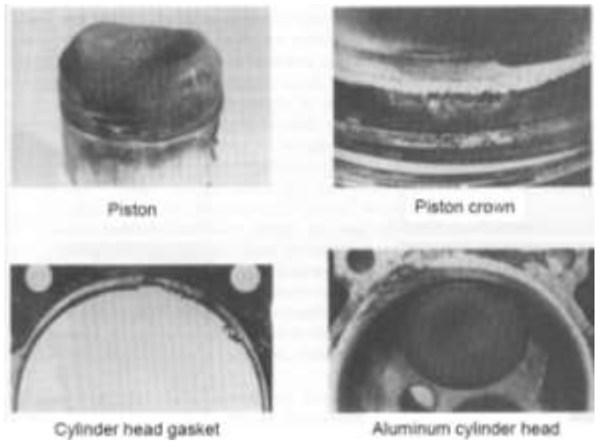


Figure 6 Effect of Knocking on engine

**Parameters affecting the Knocking:**

1. **Compression ratio:** At high compression ratios, the air / fuel mixture is compressed to high pressures and temperatures which promotes autoignition.
2. **Engine speed:** At low engine speeds, the flame velocity is slow, which gives a longer burn time, increasing the chances of knock.

   On the other hand, at high engine speeds, there is less transfer o heat to the combustion chamber walls, thus the charge temperature stays higher. This may promote knock as well. Both of these effects are competing, it is for this reason that some engines show a greater propensity to knock at high engines speeds while others do not
3. **Throttle position:** At part-throttle conditions, the residual gas fraction increases, and being a diluent, it reduces the burn rate. To compensate for this, spark ignition needs to be advanced to maximize torque. At WOT conditions, burn time

is short. Also, the initial pressure in the cylinder before compression is high, hence the final pressure is high, this increases the reaction rate of the air/fuel mixture. Even though the burn time is short, the auto-ignition effects are stronger and there is a need to retard ignition timing to avoid knock and correctly phase the combustion pressure for MBT.

4. **Intake air temperature:** A high intake temperature means a high temperature at the end of compression. If spark ignition timing is not retarded, it may well be that the pressure rise be too abrupt and either:

- Peak pressure arrives before TDC, reducing torque
- Pressure and temperature rise are too abrupt causing knock

In either case, an increase in intake air temperature demands a retardation of spark ignition timing.

**Knock Control:**

Knocking can be controlled by using spark advance. Modern engine control systems can set ignition timing advance according to engine speed and load. Load may be measured by throttle position, manifold pressure or air mass flow ( tuning parameters).

**Knock detection:**

A knock sensor is mounted on the engine block to determine if the engine is knocking. It Consists of a piezoelectric accelerometer that produces an analog electrical signal. Signal is filtered and amplified by the ECU to determine if knock is occurring.

In-cylinder pressure sensors are prohibitively expensive and fragile for use on production vehicles and are hence not used. At the onset of knock, the ECU retards spark timing by a certain number of degrees before re-increasing advance every few cycles. Correction for fuel quality and fuel type is sometimes performed via knock sensing.

**Necessity of the project:**

All the research done which is summarized above is for understanding of the EMS and further improving the Tuning and efficiency of SI engines which are already electronically fuel injected. However, the need of our project comes when one has to convert a carburetor engine into EFI and then tune it for the efficiency and performance. With the increasing pollution issues and depletion of natural resources, small carbureted engines which are massively used in bikes and generators have to converted to EFI in order to Save the fuel, control the emissions and increase the efficiency of the engine.

# CHAPTER 3: METHODOLOGY

**Methodology:**

a. Engine Selection
b. Mathematical Modelling
c. EMS
d. Wiring Schematic Diagram
e. Calibration of Sensors
f. Dyno Test Bunch
g. Dyno testing

Engine Selection:

Based on the literature review, Engine with high Compression ratio without any knocking effect and the one with Good Surface to Volume ratio has good efficiency and performance.

On the basis of this information, two small engines were selected named, GY6 50 cc engine and Honda CD 70cc engine.

Honda CD 70 cc:

Honda CD 70 has the following specs:

CR: 8.8:1

GY 6 50 cc:

GY6 has the following specs:

CR: 10.5 : 1

So based on the data, CR of GY6 is more than CD 70 so we selected GY6 to convert it to EFI using EMS.

**Mathematical Modelling:**

Calculation of Instantaneous torque:

Following is the calculation of instantaneous torque to as function of the angle of the connecting rod, hence at different angles of the piston:

From the above equation, it is clear that instantaneous torque depends on difference of Pressure in cylinder and crank case. So the cylinder pressure will be different at different rpms and at every changing angle. So, at different RPMs graph is plotted between instantaneous torque and RPM from which Average torque is calculated. Note that, at specific RPM, at every changing angle pressure would be different so in this manner engine can be tuned for the optimum average torque.

EMS:

Engine management system of the GY6 engine is selected to be RUSS EFI mainly due to the reason that it is open source as its design and software is publicly available to share and modify. Secondly it is cost effective when compared to other EMS like Micro or Mega Squirt.

The software which will be used for tuning is tuner studio as it is compatible with RUSS Efi and one is able to control all sensors with help of the software.

Wiring Harness:

The sensors which are used in an EMS are:

- TPS
- Map Sensor
- Oxygen Sensor
- CKP
- Air intake Temperature sensor
- Coolant Temperature Sensor
- Hall Sensor

The wire harness is made using these sensors according to following wiring diagram:

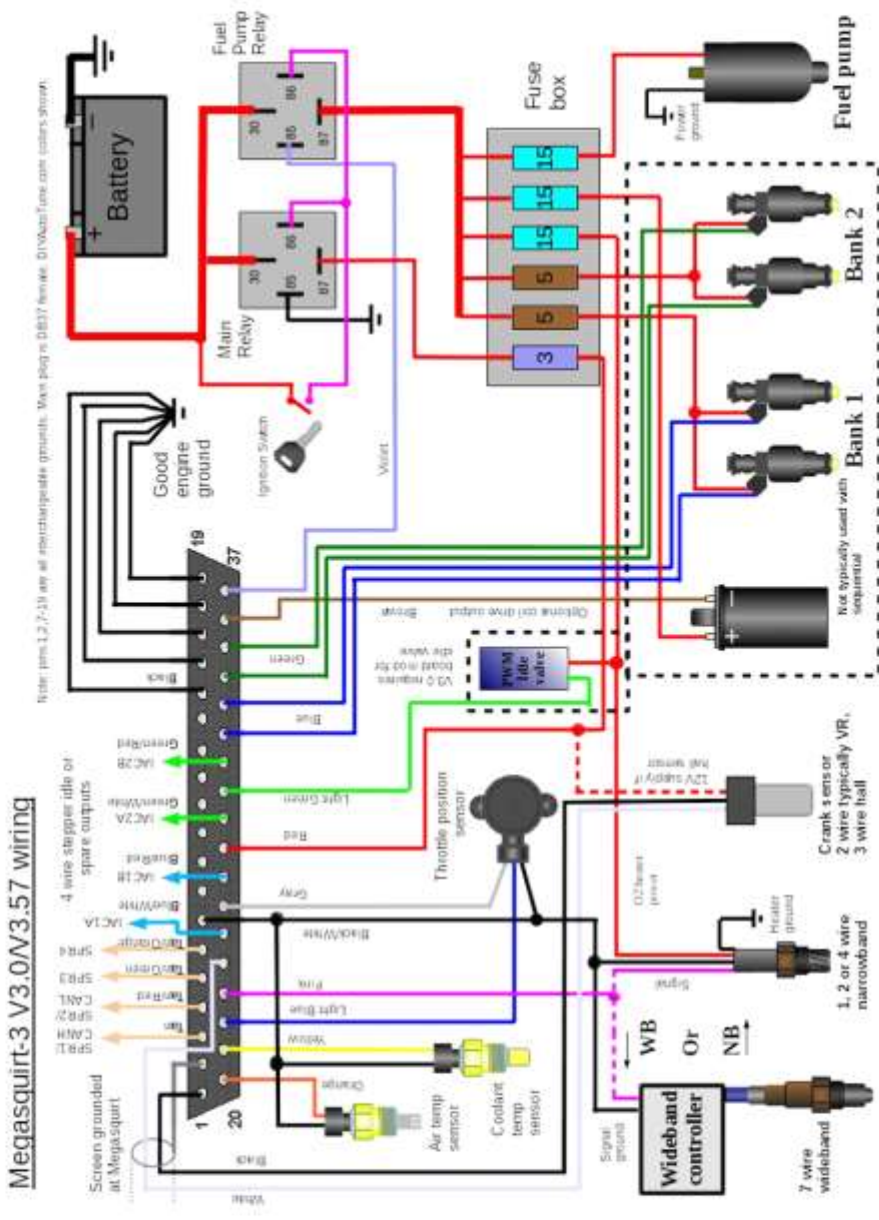


Figure 7 Wiring Diagram

**Dyno Test Bench**

Alongside calibration of sensors, Dyno test bunch according to mounting points of Gy6 will be made in order to mount the engine on Engine Dyno.

**Dyno Testing**

Engine will be tuned according to the Parameters discussed in the literature review i.e. according to Speed Density and Alpha N in order to provide the maximum Efficiency with optimum torque and power.

# CHAPTER 4: RESULTS AND DISCUSSIONS

The test vehicle on which the converted engine was implemented, the results were noted and observed. The fuel efficiency per 200 ml of fuel was increased for 22% with the implementation of EFI, operating on economy mode. Thus, the expected per liter mileage was increased from 45 km/L to around 55 km/L.

# CHAPTER 5: CONCLUSION AND RECOMMENDATION

The project was aimed at both increasing the fuel efficiency and reducing the emissions or waste fuel. The efficiency increases and dialing down of emissions was successfully achieved via implementation of the EFI kit. Further improvements could be made if the calibrations of the sensors are done more aptly and suitably for the environmental conditions of operations, that would help achieve more optimization.

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