MODELING AND DEVELOPMENT OF A SERIAL HYBRID MOTORCYCLE WITH HCCI ENGINE

A thesis submitted in partial fulfillment of the requirements for the award of the degree of

B.Tech

in

MECHANICAL ENGINEERING

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BONAFIDE CERTIFICATE

This is to certify that the project titled **MODELING AND DEVELOPMENT OF A SERIAL HYBRID MOTORCYCLE WITH HCCI ENGINE** is a bonafide record of the work done by

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in partial fulfilment of the requirements for the award of the degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING** of **COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY** at **COLLEGE OF ENGINEERING ADOOR, MANAKALA,** during the year 2011-2015.

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ABSTRACT

The greenhouse effect and limitations on carbon dioxide emissions concern engine maker and the future of the internal combustion engines should go toward substantially and improved thermal efficiency engine. Homogenous charge Combustion ignition (HCCI) engines are being considered as an alternative to diesel engines. The HCCI concept involves premixing fuel and air prior to induction in to the cylinder (as is done in current spark- ignition engine) then igniting the fuel –air mixture through the compression process (as is done in current diesel engines). Homogeneous charge compression ignition (HCCI) is an alternative high-efficiency technology for combustion engines to reduce exhaust emissions and fuel consumption. However, there are still tough challenges in the successful operation of HCCI engines, such as controlling the combustion phasing, extending the operating range, and high unburned hydrocarbon and CO emissions. HCCI and the exploitation of ethanol as an alternative fuel is one way to explore new frontiers of internal combustion engines with an eye towards maintaining its sustainability. For obtaining the above mentioned HCCI condition various modifications were made in a conventional 100cc SI engine which includes an ethanol fuel pump system, Exhaust Gas Recirculation system and series hybrid configuration. The desired increase in fuel efficiency was obtained by blending ethanol alone with gasoline i.e about100% from normal working condition.

Increase in EGR level along with ethanol blending proved to have a significant decreasing effect in engine's fuel efficiency as power is decreased.

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LIST OF ABBREVIATION

Sl no	
1	AC- Alternate Current
2	CI-Compression Ignition
3	DC- Direct Current
4	ECM-Electronic Control Module
5	EGR-Exhaust Gas Recirculation
6	EMF- Electro-Magnetic Force
7	HCCI- Homogeneous Charge Combustion Ignition
8	HCV- Higher Calorific Value
9	IMEP- Indicated Mean Effective Power
10	LCV- Lower Calorific Value
11	MOSFET-Metal Oxide Semi Conducting Field Effect Transistor
12	RPM-Rotations Per Minute
13	SC- Stratified Charge
14	SI- Spark Ignition

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1.INTRODUCTION

Lead by booming economies in China, India, and the Middle East, global energy demand is projected to increase by one-third by 2035 . A significant portion of this increase is being driven by increased demand for fossil fuels in the transportation sector. Governments and automakers in many countries have responded by allocating considerable economic resources to develop renewable fuels and fuel efficient vehicle powertrain technologies . In the international market, Electric Vehicles (EVs) and Electric Motorcycles (EMs), which have the potential to reduce fossil fuel usage, are facing challenges in consumer acceptance due to range limitations, lack of charging stations, the high cost of batteries and poor battery performance . Hybrid Electric Vehicles (HEVs), which combine the advantages of internal combustion engines and electric motors using efficient energy management strategies, are capable a meetings consumer expectations while increasing fuel economy and decreasing emissions.

Currently, both gasoline Spark Ignition (SI) and diesel Compression Ignition (CI) engines have been integrated into hybrid powertrains. CI engines have a higher thermal efficiency than SI engines, due to the higher compression ratios and lean burn ratios used. But in conventional CI engines the air/fuel charge is not pre-mixed, which leads to incomplete combustion and very high temperatures in the combustion zones. This then results in high levels of NOx and Particulate Matter (PM) emissions. SI engines, which use homogeneous (pre-mixed) air/ fuel charges and near stoichiometric air/fuel ratios, produce much lower NOx and PM emissions. However, SI engines have lower thermal efficiencies than CI engines due to the lower compression ratios used to prevent engine knock and throttling losses during Partial Open Throttle (POT) operation.

Homogeneous Charge Compression Ignition (HCCI) engines combine the advantages of both SI and CI engines. The direct injection used in HCCI engines allows higher compression ratios to be used than in conventional SI engines, which improves efficiency to levels comparable to CI engines. The very lean homogeneous air/fuel charge in the HCCI engine is burned volumetrically, which greatly reduces the in-cylinder

temperature and in turn greatly reducing the production of NOx. The charge is also sufficiently well-mixed to reduce the production of soot
. A difficulty with HCCI engines is controlling the combustion process to allow HCCI operation over a wide range of speeds and loads .

In a series hybrid powertrain, the internal combustion engine is typically run at a constant speed to drive the generator. This makes it is possible to utilize HCCI engine in series hybrid powertrain, because it is difficult to control the torque and speed of an HCCI engine simultaneously. While integrating the HCCI engine into a serial hybrid powertrain, in order to increase the electrical power generated, the state engine speed and load should be increased. Thus in this research, several methodology are developed. According to the burning characteristics of HCCI engine , utilization of mixed fuel and external Exhaust Gas Recirculation (EGR) [are realized, then the HCCI state speed and torque can be increased to 3000~7000 rpm , which upgrades the possibility of utilizing HCCI engine in serial hybrid powertrain.

The desired increase in fuel efficiency was obtained by blending ethanol alone with gasoline i.e about100% from normal working condition. Increase in EGR level along with ethanol blending proved to have a significant decreasing effect in engine's fuel efficiency as power is decreased.

1.1 HCCI ENGINE

Homogeneous charge compression ignition (HCCI) is a form of internal combustion in which well-mixed fuel and oxidizer (typically air) are compressed to the point of auto-ignition. As in other forms of combustion, this exothermic reaction releases chemical energy into a sensible form that can be transformed in an engine into work and heat. HCCI combines characteristics of conventional gasoline engine and diesel engines. Gasoline engines combine homogeneous charge (HC) with spark ignition (SI), abbreviated as HCSI. Diesel engines combine stratified charge (SC) with compression ignition (CI), abbreviated as SCCI.

As in HCSI, HCCI injects fuel during the intake stroke. However, rather than using an electric discharge (spark) to ignite a portion of the mixture, HCCI raises density and temperature by compression until the entire mixture reacts spontaneously.

Stratified charge compression ignition also relies on temperature and density increase resulting from compression. However, it injects fuel later, during the compression stroke. Combustion occurs at the boundary of the fuel and air, producing higher emissions, but allowing a leaner and higher compression burn, producing greater efficiency.

Controlling HCCI requires microprocessor control and physical understanding of the ignition process. HCCI designs achieve gasoline engine-like emissions with diesel engine-like efficiency.

HCCI engines achieve extremely low levels of Nitrogen oxide emissions (NO x) without a catalytic converter. Unburned hydrocarbon and carbon monoxide emissions still require treatment to meet automotive emission regulations.

Recent research has shown that the hybrid fuels combining different reactivities (such as gasoline and diesel) can help in controlling HCCI ignition and burn rates. RCCI or Reactivity Controlled Compression Ignition has been demonstrated to provide highly efficient, low emissions operation over wide load and speed ranges.

1.2 ETHANOL AS ADDITIVE

A HCCI engine fuelled with ethanol is a new and promising concept currently being explored by engine researchers as the next-generation of ICEs. Most researchers conducted between 1997 and 2006 sought to improve ethanol fuel HCCI engines by employing supercharging technology, fuel reforming, residual gas trapping, valve timing and force induction. Christensen et al. did the first study on ethanol fuelled HCCI engine and showed ethanol is a good alternative as a gasoline fuel replacement. In this study, HCCI engine was operated unthrottled with very lean mixture, generating no NOx emission. Christensen et al. used supercharger to boost pressure in HCCI engine. The results showed that achieving more IMEP for HCCI is noticeably related to application of a supercharger. Boosting pressure reduces HC emission while NOx values drop. They showed that the main benefit of HCCI is the low level of exhaust NOx emission. Ng and Thomson investigated the effect of fuel reforming and EGR on HCCI operation by using a single zone reactor model and reaction mechanisms. They applied hydrogen and CO for reforming which widened the operating range of HCCI engine. Hydrogen can be used as additive due to its wide flammability limits. The results showed that EGR was more effective than reforming in widening the operating range. Moreover, reforming was practical in HCCI combustion to maintain complete combustion at lower intake temperature. Yap et al. studied internal residual gas trapping in a naturally aspirated HCCI engine. Residual gas trapping was used with internal trapping of exhaust gas to lower the thermal energy requirements for the autoignition of the air-fuel mixture. Moderate Tin extends the engine operation range of bioethanol fuelled HCCI engine. The NOx emissions were reported as low due to the nature of homogeneous combustion. They also reported that high pressure rise rates (at higher AFR) are the reason HCCI operations are limited. The application of intake air preheating with internal trapping of exhaust gas improves the liquid fuel evaporation. Yap et al. extended their work using forced induction in conjunction with residual gas trapping and showed that the usable operation range of bio-ethanol fuelled HCCI could be increased effectively by using forced induction and trapping of residual gas. Combustion phasing could be controlled by boost. An increase in trapped residuals gas could lower the maximum possible load at given boost pressure. Using increased trapped residuals gas with higher boosting pressure make NOx emission levels lower. However CO emissions increased due to increased pumping losses.

1.3 EXHAUST GAS RECIRCULATION (EGR)

In internal combustion engines, exhaust gas recirculation (EGR) is a nitrogen oxide (NO_x) emissions reduction technique used in petrol/gasoline and diesel engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. Exhaust gas is routed back into the combustion chamber because the exhausted air is much hotter than the intake air. EGR works by diluting the N2 and providing gases inert to combustion (CO2 primarily) to act as an absorbent of combustion heat to reduce peak in cylinder temperatures. NOx is produced in a narrow band of high cylinder temperatures and pressures.

In a gasoline engine, this inert exhaust displaces the amount of combustible matter in the cylinder. In a diesel engine, the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture. Because NOx forms primarily when a mixture of nitrogen and oxygen is subjected to high temperature, the lower combustion chamber temperatures caused by EGR reduces the amount of NOx the combustion generates (though at some loss of engine efficiency). Gasses re-introduced from EGR systems will also contain near equilibrium concentrations of NOx and CO; the small fraction initially within the combustion chamber inhibits the total net production of these and other pollutants when sampled on a time average. Most modern engines now require exhaust gas recirculation to meet emissions standards.

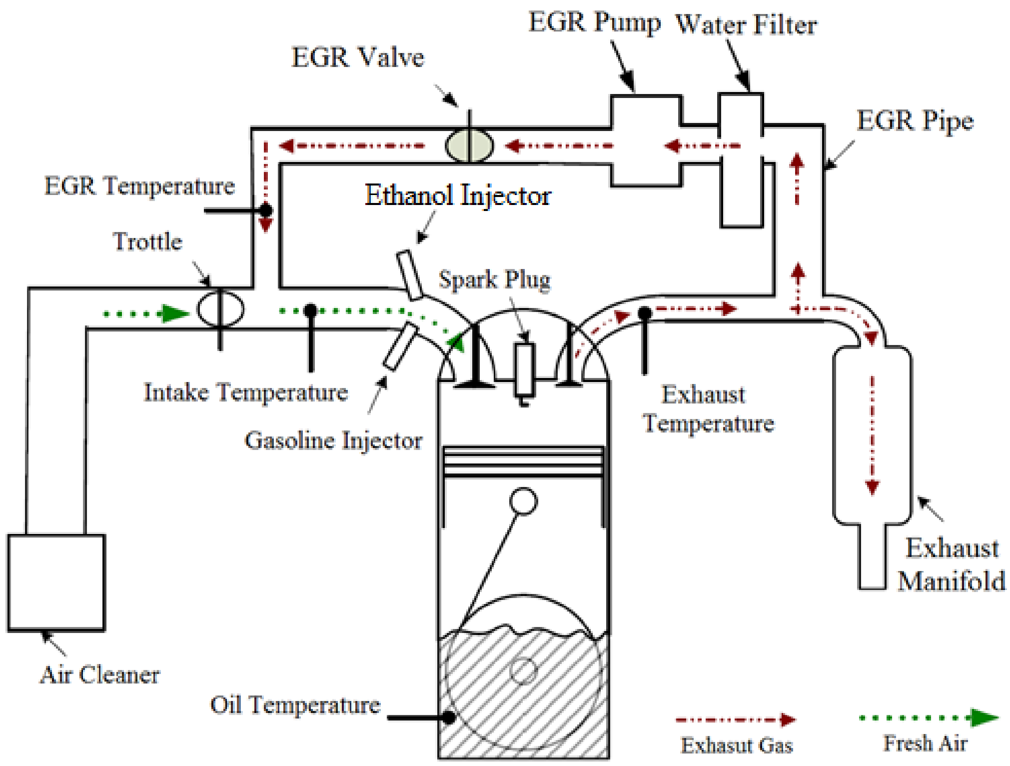


Fig 1.1 EGR System

1.4 HYBRID SERIES CONFIGURATION

After the HCCI engine modifications were completed, the engine along with other series hybrid components (generator, battery and electric motor) was integrated on board a 150 c.c. engine

1.4.1 DC GENERATOR

An electrical Generator is a machine which converts mechanical energy (or power) into electrical energy (or power)

PRINCIPLE:

It is based on the principle of production of dynamically (or motionally) induced e.m.f (Electromotive Force). Whenever a conductor cuts magnetic flux, dynamically induced e.m.f. is produced in it according to Faraday's Laws of Electromagnetic Induction. This e.m.f. causes a current to flow if the conductor circuit is closed.

Hence, the basic essential parts of an electric generator are:

- A magnetic field and
- A conductor or conductors which can so move as to cut the flux.

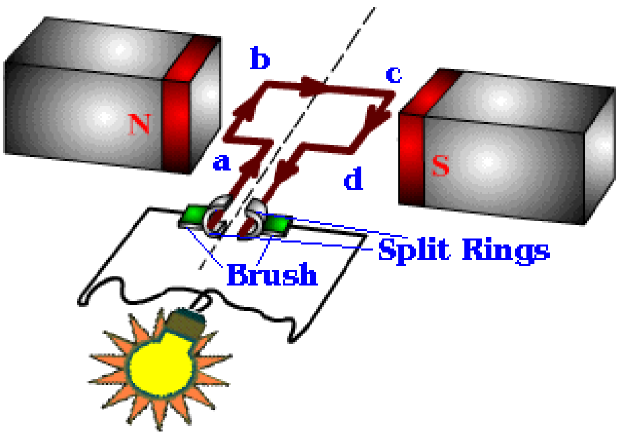


Fig1.2 DC Generator

CONSTRUCTION:

A single-turn rectangular copper coil abcd moving about its own axis in a magnetic field provided by either permanent magnets or electromagnets. The two ends of the coil are joined to two split-rings which are insulated from each other and from the central shaft. Two collecting brushes (of carbon or copper) press against the slip rings.

1.4.2BATTERY

In isolated systems away from the grid, batteries are used for storage of excess solar energy converted into electrical energy. The only exceptions are isolated sunshine load such as irrigation pumps or drinking water supplies for storage. In fact for small units with output less than one kilowatt.

Batteries seem to be the only technically and economically available storage means. Since both the photo-voltaic system and batteries are high in capital costs. It is necessary that the overall system be optimized with respect to available energy and local demand pattern. To be economically attractive the storage of solar electricity requires a battery with a particular combination of properties:

(1) Low cost
(2) Long life
(3) High reliability
(4) High overall efficiency
(5) Low discharge
(6) Minimum maintenance

We use lead acid battery for storing the electrical energy from the solar panel for lighting the street and so about the lead acid cells are explained below.

LEAD-ACID WET CELL

Where high values of load current are necessary, the lead-acid cell is the type most commonly used. The electrolyte is a dilute solution of sulfuric acid (H_2SO_4). In the application of battery power to start the engine in an auto mobile, for example, the load current to the starter motor is typically 200 to 400A. One cell has a nominal output of 2.1V, but lead-acid cells are often used in a series combination of three for a 6-V battery and six for a 12-V battery.

The lead acid cell type is a secondary cell or storage cell, which can be recharged. The charge and discharge cycle can be repeated many times to restore the output voltage, as long as the cell is in good physical condition. However, heat with excessive charge and discharge currents shortends the useful life to about 3 to 5 years for an automobile battery. Of the different types of secondary cells, the lead-acid type has the highest output voltage, which allows fewer cells for a specified battery voltage.

CONSTRUCTION:

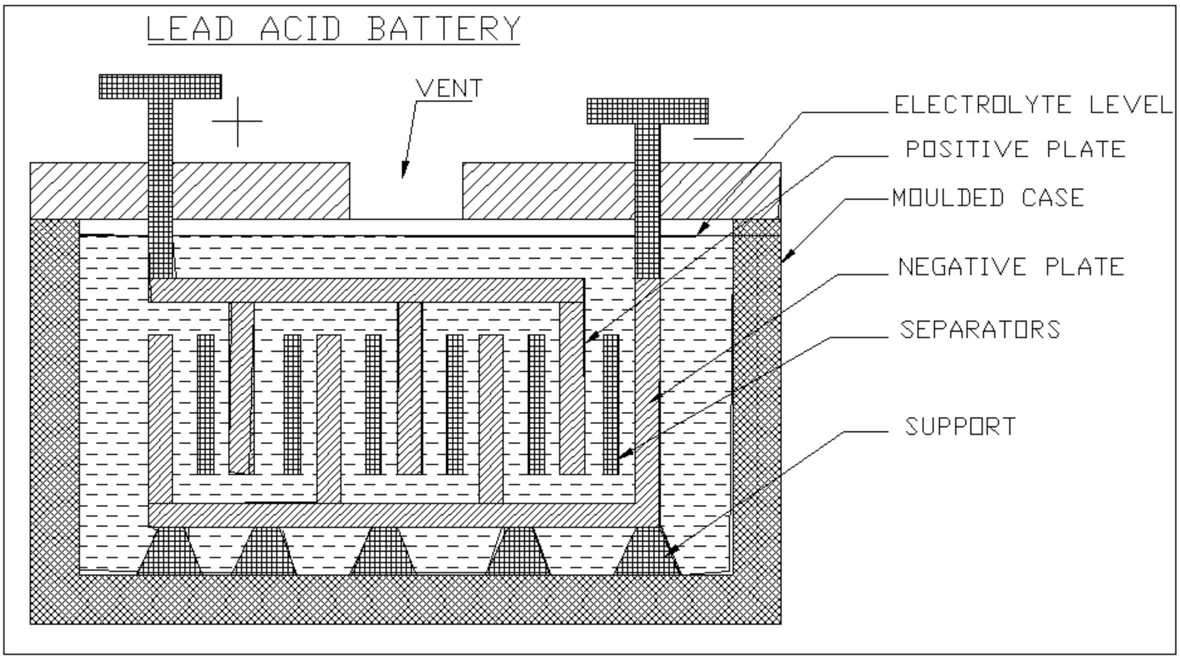


Fig 1.3 LeadAcid Wet Cell

Inside a lead-acid battery, the positive and negative electrodes consist of a group of plates welded to a connecting strap. The plates are immersed in the electrolyte, consisting of 8 parts of water to 3 parts of concentrated sulfuric acid. Each plate is a grid or framework, made of a lead-antimony all This construction enables the active material, which is lead oxide, to be pasted into the grid. In manufacture of the cell, a forming charge produces the positive and negative electrodes. In the forming process, the active material in the positive plate is changed to lead peroxide (pbo_2). The negative electrode is spongy lead (pb).

Automobile batteries are usually shipped dry from the manufacturer. The electrolyte is put in at the time of installation, and then the battery is charged to from the plates. With maintenance-free batteries, little or no water need be added in normal service. Some types are sealed, except for a pressure vent, without provision for adding water.

CHEMICAL ACTION:

Sulfuric acid is a combination of hydrogen and sulfate ions. When the cell discharges, lead peroxide from the positive electrode combines with hydrogen ions to form water and with sulfate ions to form lead sulfate. Combining lead on the negative plate with sulfate ions also produces he sulfate.

There fore, the net result of discharge is to produce more water, which dilutes the electrolyte, and to form lead sulfate on the plates. As the discharge continues, the sulfate fills the pores of the grids, retarding circulation of acid in the active material. Lead sulfate is the powder often seen on the outside terminals of old batteries. When the combination of weak electrolyte and sulfating on the plate lowers the output of the battery, charging is necessary. On charge, the external D.C. source reverses the current in the battery. The reversed direction of ions flows in the electrolyte result in a reversal of the chemical reactions. Now the lead sulfates on the positive plate reactive with the water and sulfate ions to produce lead peroxide and sulfuric acid. This action re-forms the positive plates and makes the electrolyte stronger by adding sulfuric acid.

At the same time, charging enables the lead sulfate on the negative plate to react with hydrogen ions; this also forms sulfuric acid while reforming lead on the negative plate to react with hydrogen ions; this also forms currents can restore the cell to full output, with lead peroxide on the positive plates, spongy lead on the negative plate, and the required concentration of sulfuric acid in the electrolyte.

The chemical equation for the lead-acid cell is

Charge

$Pb + pbO_2 + 2H_2SO_4 \rightleftharpoons 2pbSO_4 + 2H_2O$

Discharge

On discharge, the pb and pbo_2 combine with the SO_4 ions at the left side of the equation to form lead sulfate ($pbSO_4$) and water (H_2O) at the right side of the equation. One battery consists of 6 cell, each have an output voltage of 2.1V, which are connected in series to get an voltage of 12V and the same 12V battery is connected in series, to get an 24 V battery. They are placed in the water proof iron casing box.

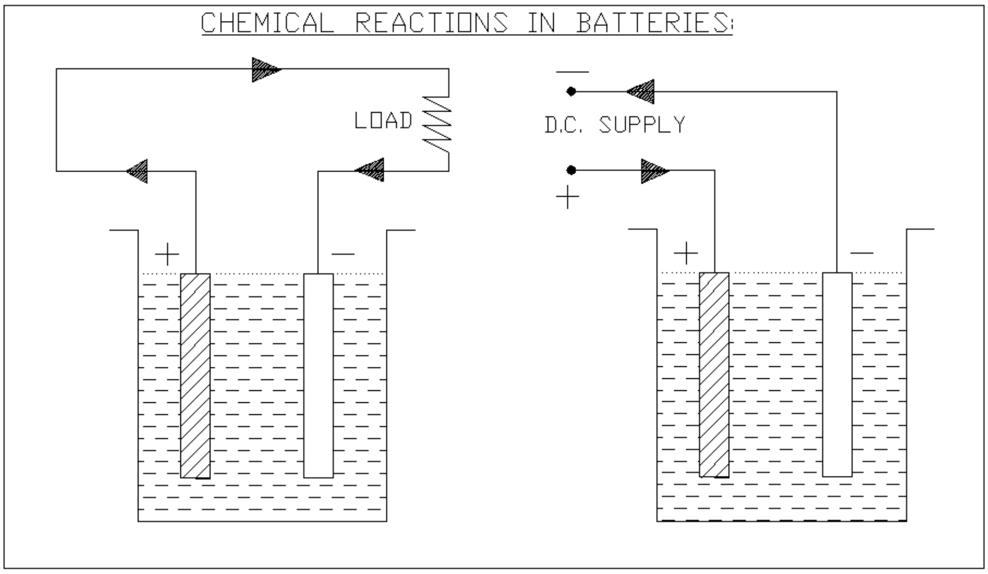


Fig 1.4 Chemical Reactions In Battery

CHARGING THE LEAD-ACID BATERY:

The requirements are illustrated in figure. An external D.C. voltage source is necessary to produce current in one direction. Also, the charging voltage must be more than the battery e.m.f. Approximately 2.5 per cell are enough to over the cell e.m.f. so that the charging voltage can produce current opposite to the direction of discharge current.

Note that the reversal of current is obtained just by connecting the battery VB and charging source VG with + to + and –to-, as shown in figure. The charging current is reversed because the battery effectively becomes a load resistance for VG when it higher than VB. In this example, the net voltage available to produce charging currents is 15-12=3V.

A commercial charger for automobile batteries is essentially a D.C. power supply, rectifying input from the AC power line to provide D.C. output for charging batteries. Float charging refers to a method in which the charger and the battery are always connected to each other for supplying current to the load. In figure the charger provides current for the load and the current necessary to keep the battery fully charged. The battery here is an auxiliary source for D.C. power.

It may be of interest to note that an automobile battery is in a floating-charge circuit. The battery charger is an AC generator or alternator with rectifier diodes, driver by a belt from the engine. When you start the car, the battery supplies the cranking power. Once the engine is running, the alternator charges he battery. It is not necessary for the car to be moving. A voltage regulator is used in this system to maintain the output at approximately 13 to 15 V.

The constant voltage of 24V comes from the solar panel controlled by the charge controller so for storing this energy we need a 24V battery so two 12V battery are connected in series. It is a good idea to do an equalizing charge when some cells show a variation of 0.05 specific gravity from each other. This is a long steady overcharge, bringing the battery to a gassing or bubbling state. Do not equalize sealed or gel type batteries. With proper care, lead-acid batteries will have a long service life and work very well in almost any power system. Unfortunately, with poor treatment lead-acid battery life will be very short.

2.REVIEW OF LITERATURE

From literature of M. Mardi K et.al (January 2015) [2],it was found that literature demonstrates that the use of ethanol–gasoline blended fuels will marginally increase the engine power. It was also found that the CO_2 and NOx concentrations increased while the concentrations of CO and HC decreased when ethanol–gasoline blends are used. Increasing EGR level proved to have a significant decreasing effect on engine power. From the viewpoint of emissions, EGR have a slight emission reducing effect on CO and HC levels up to 10% of EGR and a notable plummet in NOx emission levels.

From literature of Alireza Rahbari et .al(March 2012) [3],it was found that ,in an HCCI engine, auto ignition first occurs at local in-homogeneities which overcome their threshold energies to the chain branching reactions faster due to specific heat differences .For a temperature range of 900-1100 K chain branching occurs which is the minimum condition for auto ignition.

From literature of Yuh-Yih Wu et .al(2013) [4],certain crucial details were obtained which includes

- HCCI engine combustion process
- Dual fuel strategy for HCCI engine mode
- Use of Exhaust Gas Recirculation system
- Hybrid series configuration
- Prediction of fuel economy

Prof. Sanjay Harip[1] ,2009 June showed that HCCI engine has High efficiency and ultra low emission w.r.t conventional Diesel engine. To achieve near zero NOx and soot emission to achieve latest Euro Norms . To reduce fuel consumption, greenhouse gas emission. Effective Control System for ignition timing .To achieve practically Variable Compression ratio. Injection strategy w.r.t load condition

3.METHADOLOGY

3.1 MATERIALS

3.1.1 ETHANOL

Ethanol also commonly called alcohol, spirits, ethyl alcohol, and drinking alcohol, is the principal type of alcohol found in alcoholic beverages, produced by the fermentation of sugars by yeasts. It is a neurotoxic psychoactive drug and one of the oldest recreational drugs used by humans. It can cause alcohol intoxication when consumed in sufficient quantity. Ethanol is used as a solvent, an antiseptic, a fuel and the active fluid in modern (post-mercury) thermometers (since it has a low freezing point). It is a volatile, flammable, colourless liquid with a strong chemical odour. Its structural formula CH3CH2OH s often abbreviated as
C2H5OH, C2H6O or EtOH.

3.1.2 GASOLINE

Gasoline known as petrol outside of North America, is a transparent, petroleum-derived liquid that is used primarily as a fuel in internal combustion engines. It consists mostly of organic compounds obtained by the fractional distillation of petroleum, enhanced with a variety of additives; a 42-gallon barrel of crude oil yields about 19 gallons of gasoline, when processed in an oil refinery. The characteristic of a particular gasoline blend to resist igniting too early (which causes knocking and reduces efficiency in reciprocating engines) is measured by its octane rating. Gasoline is produced in several grades of octane rating.

3.1.3 CAST IRON

Cast iron is iron or a ferrous alloy which has been heated until it liquifies, and is then poured into a mould to solidify. It is usually made from pig iron. The alloy constituents affect its colour when fractured: white cast iron has carbide impurities which allow cracks to pass straight through. the melting temperatures closely correlate, usually ranging from 1,150 to 1,200 °C (2,100 to 2,190 °F), which is about 300 °C (572 °F) lower than the melting point of pure iron. Cast iron tends to be brittle, except for malleable cast irons. With its relatively low melting point, good fluidity, castability, excellent machinability, resistance to deformation and wear resistance, cast irons have become an engineering material with a wide range of applications and are used in pipes, machines and automotive industry parts, such as cylinder heads (declining usage), cylinder blocks and gearbox cases (declining usage). It is resistant to destruction and weakening by oxidation (rust).

3.1.4 MILD STEEL

Mild steel also known as plain-carbon steel, is now the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Low-carbon steel contains approximately 0.05–0.15% carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and easy to form; surface hardness can be increased through carburizing.

It is often used when large quantities of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm^3 (7850 kg/m^3 or 0.284 lb/in^3) and the Young's modulus is 210 GPa (30,000,000 psi).

Low-carbon steels suffer from yield-point runout where the material has two yield points. The first yield point (or upper yield point) is higher than the second and the yield drops dramatically after the upper yield point. If a low-carbon steel is only stressed to some point between the upper and lower yield point then the surface may develop Lüder bands. Low-carbon steels contain less carbon than other steels and are easier to cold-form, making them easier to handle.

3.2 EXPERIMENTAL SETUP

There were different modifications done to develop the model for running the test for fuel economy they are:-

1) Welding
2) drilling
3) Ethanol injection system
4) EGR system
5) Series hybrid configuration

3.2.1 WELDING

Mild steel of different lengths were welded together to form a frame work for the fixation of the engine, ethanol feed system, fuel tank, buret, series hybrid configuration(Motor, Battery and speed control for the motor) and a chain drive from the motor to a wheel which is also attached to the frame. the frame after welding is shown below.

Fig 3.1 frame after welding

3.2.2 DRILLING

Drilling was done in the inlet manifold to place a ethanol fuel injector. Vertical drilling technique was used for the purpose. The diagram of inlet manifold after drilling is shown below.

Fig3.2 inlet manifold after drilling

3.2.3 ETHANOL INJECTION SYSTEM

Ethanol injection system consists of;

3.2.3.1 Fuel Pump :-

The electrical fuel pump located on the fuel tank consists of armature, magnet, impeller, brush, check valve etc. The ECM controls its operation. When the power is supplied to the fuel pump, the motor in the pump runs and so does the impeller. This causes a pressure difference to occur between both sides of the impeller, as there are many grooves around it. Then the fuel is drawn through the inlet port, and with its pressure increases, It is discharged through the outlet port.its specification is 12V and 10W.

fig3.3 Ethanol fuel pump

3.2.3.2 Ethanol control circuit:-

Ethanol control unit is a 5 5 5 turning control unit(variable resistor) which controls various devices according to the signals from the sensors and various controlled devices.

Fuel injection control system :- With the help of variable resistor we can control the flow of ethanol to the combustion chamber. It uses the electromagnetic multi-port fuel injection system, which injects ethanol into intake port of the cylinder head. it allows a range of 2-5 mL of ethanol fuel per second.

Fuel pump control system:- Fuel pump control system ECM controls ON/OFF operation of the fuel pump by turning it ON, the fuel pump relay under our condition.

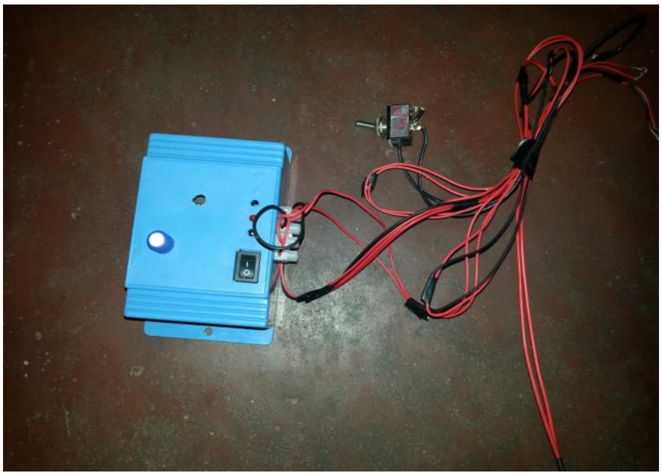


fig3.4 Ethanol control unit

3.2.3.3 Ethanol fuel injector:- A hole is drilled according to the size of the injector and injector is fixed on the inlet manifold. M seal and araldite is used to fix the injector on the manifold **.**It is an electromagnetic type injection nozzle, which injects fuel into the intake port of the cylinder head according to the signal from ECM. When the solenoid coil of the injector is energised by ECM, it becomes an Electro magnet and attracts the plunger. At the same time, the ball valve which is incorporated with the plunger opens and the injector which is under the fuel pressure injects fuel. As the lift stroke of the ball valve of the injector is set constant, the amount of fuel injected at one time is determined by the length of the time during which the solenoid is energized .its specification is 12 V and 10W.

fig 3.5 Ethanol fuel injector

fig 3.6 installation of ethanol fuel injector

3.2.4 EGR system:-

EGR system associates with exhaust gas recirculation for HCCI engine mode.This system consists of an emission filter box of dimension 8 inch*8 inch*8 inch omade of mild steel. Hot exhaust gas is allowed to pass through the box small tubes which contain certain holes inside emission filter box. the box is filled with engine oil "POWER1 4T 10W-30" to a level which just immerses the holes. As the hot air flows through these tubes oil cools it. Cooling of exhaust gas is made without its abscence , supplying exhaust gas to the engine air inlet valve will cease the engine to stop. After cooling the air is flowed through a water filter to absorb the water vapour content. Amount of exhaust gas supplied to the engine air inlet manifold is controlled using gate valves.

fig 3.7 Inside view of emission filter box

fig 3.8 EGR system installed on the frame

3.2.5 Series hybrid configuration:-

Series hybrid configuration includes a 2* 12V battery, dc motor(24 volts,150 watt,600 rpm, permanent magnet type), MOSFET fed speed control unit . Electrical power from engine dynamo while running is used to charge the battery. DC motor is then used to drive the wheel coupled using the charge from battery via speed control unit. Speed control unit consists of a micro control unit, driver unit with a variable resistor circuit.

fig 3.9 DC motor

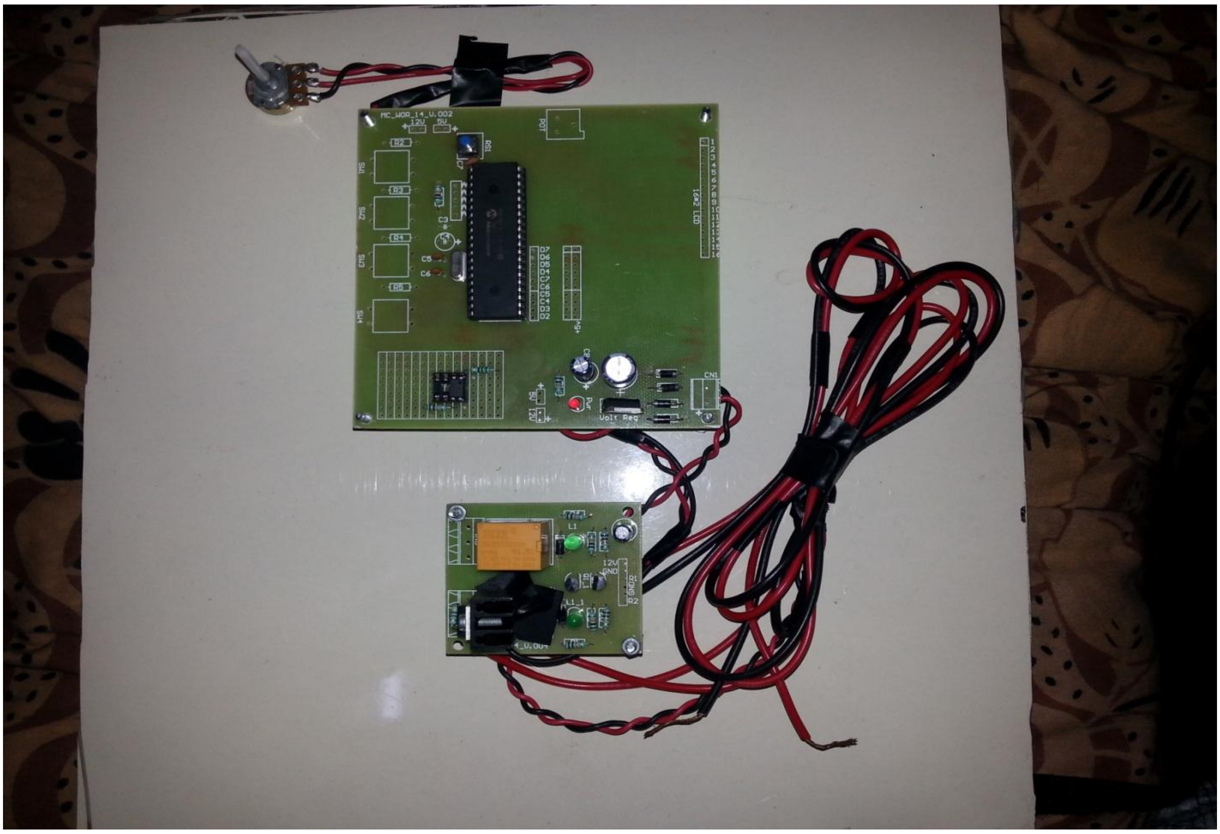


fig 3.10speed control unit

3.3 CRITERIA FOR ENGINE SELECTION

As per the literature [3],minimum combustion temperature lies in the range 900 K - 1150K for auto ignition. So as the desired temperature and pressure was enough for auto-ignition to take place the engine with specified conditions was selected for the project.

3.3.1 SPECIFICATION OF FOUR STROKE PETROL ENGINE:

Type	:	four stroke
Cooling System	:	Air Cooled
Bore/Stroke	:	50 x 50 mm
Piston Displacement	:	98.2 cc
Compression Ratio	:	6.6: 1
Maximum Torque	:	0.98 kg-m at 5,500RPM

3.3.2 CALCULATION:

Compression ratio = (Swept Volume + Clearance Volume)/ Clearance Volume

Here,

Compression ratio = 6.6:1

Clearance volume = V_c

$\therefore 6.6 = (98.2 + V_c)/V_c$

$V_c = 19.64$

Assumption:

1. The component gases and the mixture behave like ideal gases.

$$PV= NRT$$

2. Mixture obeys the Gibbs-Dalton

Here,

P = Pressure exerted at different conditions on cylinder

N = m/M = (Mass of the gas or air)/(Molecular Weight)

R = Universal gas constant = 8.314 J/mole K.

T = Specified temperature condition

V = Total volume of cylinder = 117.84×10^{-6} m³

Molecular weight of air = Density of air x V mole

Here,

Density of air at 303 K = 1.165 kg/m³

V mole = 22.4 m³/Kg-mole for all gases.

∴Molecular weight of air = 1.165 x 22.4 per mole

Let P_1 be pressure exerted by air and m_1 be the mass of air.

$\therefore P_1 = \{[(m_1/(1.165 \times 22.4)] \times 8.314 \times 303\}/117.84 \times 10^{-6}$

$P_1 = 381134.1\ m_1$

Let Pressure exerted by the fuel is P_2 and m_2 be the mass of fuel.

$P_2 = (N_2 \overline{R} T)/V$

Density of petrol = 800 Kg/m³

$\therefore P_2 = \{[(m_2)/(800 \times 22.4)] \times 8.314 \times 303\}/(235.28 \times 10^{-6})$

$P_2 = 597.49\ m_2$

Therefore Total pressure inside the cylinder

$P_T \quad = \quad P_1 + P_2$

$\quad = \quad 1.01325 \times 100 \ KN/m^2$

$\therefore 819192.5\ m_1 + 1192.9\ m_2 \quad = \quad 1.01325 \times 100$ ------------------------- (1)

Calculation of air fuel ratio**:**

Carbon = 86%

Hydrogen = 14%

We know that,

1Kg of carbon requires 8/3 Kg of oxygen for the complete combustion.

1Kg of sulphur requires 1 Kg of Oxigen for its complete combustion.

Therefore,

The total oxygen requires for complete combustion of 1 Kg of fuel

$= \quad [((8/3)C) + (3H_2) + S]$ Kg

Little of oxygen may already present in the fuel, then the total oxygen required for complete combustion of Kg of fuel

$= \quad \{ [((8/3)C) + (8H_2) + S] - O_2\}$ Kg

As air contains 23% by weight of Oxygen for obtain of oxygen amount of air required = 100/23 Kg

$\therefore$Minimum air required for complete combustion of 1 Kg of fuel

= (100/23) { [((8/3)C) + H_2 + S] - O_2}

Kg

So for petrol 1Kg of fuel requires = (100/23) { [(8/3) x 0.86 + (8 x 0.14)

] }

= 14.84 Kg of air

∴Air fuel ratio = m_1/ m_2 = 14.84/1

= 14.84

∴ m_1 = 14.84 m_2-------------------------- (2)

Substitute (2) in (1)

1.01325 x 100 = 8.19192 (14.84 m_2) + .011929 m_2

∴ m_2 = 1. 19x 10^{-5} Kg/Cycle

Mass of fuel flow per cycle = 1.19 x 10^{-5} Kg/ cycle

Therefore,

Mass flow rate of the fuel for 2500 RPM

[(1.19 x 10^{-5})/3600] x (2500/2) x 60

= 2.479 x 10^{-4} Kg/sec

Calculation of calorific value**:**

By Delong's formula,

HCV = Higher Calorific Value

LCV = Lower Calorific Value

C_p = specific heat at constant pressure

C_v= specific heat at constant volume

Higher Calorific Value = 33800 C + 144000 H_2 + 9270 S

= (33800 x 0.86) + (144000 x 0.14) + 0

HCV = 49228 KJ/Kg

Lower Calorific Value = HCV – ($9H_2$ x 2442)

= 49228 – [(9 x 0.14) x 2442]

= 46151.08 KJ/Kg

LCV = 46.151 MJ/Kg

Finding C_p and C_v for the mixture:

We know that,

Air contains 77% N_2 and 23% O_2 by weight

But total mass inside the cylinder = $m_1 + m_2$

= $1.76 \times 10^{-4} + 1.19 \times 10^{-5}$ Kg

= 1.885×10^{-4} Kg

(1) Weight of nitrogen present = 77% = 0.77 Kg in 1 Kg of air

∴In 2.65×10^{-4} Kg of air contains,

= $0.77 \times 1.76 \times 10^{-4}$ Kg of N_2

= 1.3552×10^{-4} Kg

Percent of N_2 present in the total mass

= $(1.3552 \times 10^{-4}/1.885 \times 10^{-4})$

= 72.125 %

(1) Percentage of oxygen present in 1 Kg of air is 23%

Percentage of oxygen present in total mass

= $(0.23 \times 1.76 \times 10^{-4})/(1.885 \times 10^{-4})$

= 21.54 %

(2) Percentage of carbon present in 1 Kg of fuel 86%

Percentage of carbon present in total mass

$$= (0.866 \times 1.19 \times 10^{-5})/(1.885 \times 10^{-4})$$

$$= 5.444\%$$

(3) Percentage of Hydrogen present in 1 Kg of fuel 14%

Percentage of Hydrogen present in total mass

$$= (0.14 \times 1.19 \times 10^{-5})/(1.885 \times 10^{-4})$$

$$= 8.86\%$$

Total Cp of the mixture is $= \Sigma m_i Cp_i$

$$C_p = (0.72125 \times 1.043) + (0.2154 \times 0.913) + (0.54444 \times 0.7) + (.08838 \times 14.257)$$

$$C_p = 2.5885 KJ/Kg.K$$

$$C_v = \Sigma m_i Cv_i$$

$$= (0.72125 \times 0.745) + (0.2154 \times 0.653) + (0.05444 \times 0.5486) + (.08838 \times 10.1333)$$

$$= 1.871\ KJ/Kg.K$$

n For the mixture $= (C_p/C_v)$

$$= 2.5885/1.871$$

$$n = 1.38$$

Pressure and temperature at various PH**:**

p_1 = 1.01325 bar

t_1 = 30°C = 303 K

p_2/p_1 = $(r)^{n-1}$

Where,

p_1 = 1.01325 bar

r = 6.6

n = 1.38

$\therefore p_2$ = 13.698 bar

t_2 = $(r)^{n-1} \times t_1$

Where,

t_1 = 303 K

$\therefore t_2$ = 620.68 K

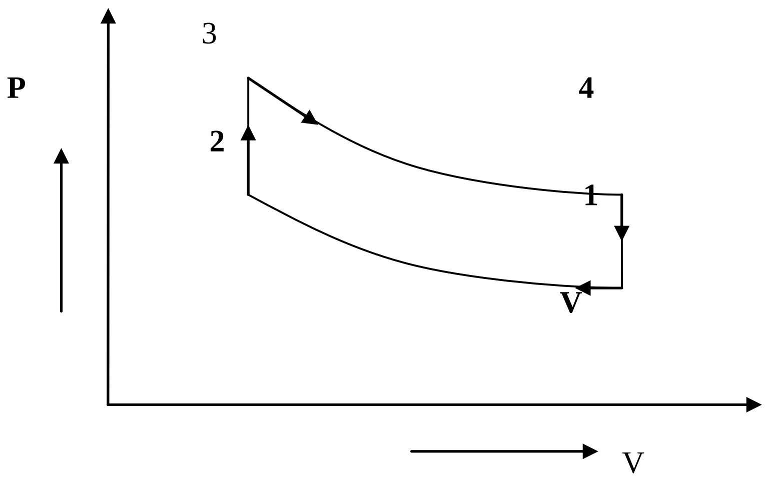


fig3.11 P-V Diagram

Heat Supplied by the fuel per cycle = Q

Q = M*LCV

$= 1.79 \times 10^{-5} \times 46151.08$

$Q = 0.8265$ KJ/Cycle

$0.8265 = M\,Cv\,(t_3 - t_2)$

$= 1.79 \times 10^{-5} \times 0.8 \times (t_3 - t_2)$

$t_3 = 4272.45$ K

$(p_2 v_2) / t_2 = (p_3 v_3) / t_3$

Where,

$v_2 = v_3$

$\therefore p_3 = (t_3 \times p_2) / t_2$

Where,

$p_3 = 94.27$ bar

$p_4 = p_3 / (r)^n$

$\therefore p_4 = 6.973$ bar

$t_4 = t_3 / (r)^{n-1}$

$= 2086.15$ K

POINT POSITION	**PRESSURE (bar)**	**TEMPERATURE**	
POINT-1	1.01325	30 °C	303 K
POINT-2	13.698	347.68 °C	620.68 K
POINT-3	94.27	3999.45 °C	4272.45 K
POINT-4	6.973	1813.15 °C	2086.15 K

Table 3.1 calculated temperature and pressure

So as the desired temperature and pressure was enough for auto-ignition to take place the engine with specified conditions was selected for the project.

3.4EXPERIMENTAL PROCEDURE

1) Petrol is filled into the burette .

2) The engine is started and initially given an acceleration.

3) RPM is adjusted to desired value by adjusting the throttle valve screw in the carburetor.

4) Time for 10ml decrease in the quantity of petrol is noted down using a stop watch.

5) Step 4 is repeated for different RPM and noted down.

6) Ethanol is poured into the ethanol tank and fuel feed pump is started and the ethanol injection valve is made such that maximum injection is done.

7) Then step 4 is again repeated for different RPMs and noted down.

8) EGR system is also made to re-circulate the exhaust gas back into the air intake.

9) Step 4 is again repeated for different values of RPM and noted down.

10) Graphs are plotted based on the values and the graphs are compared.

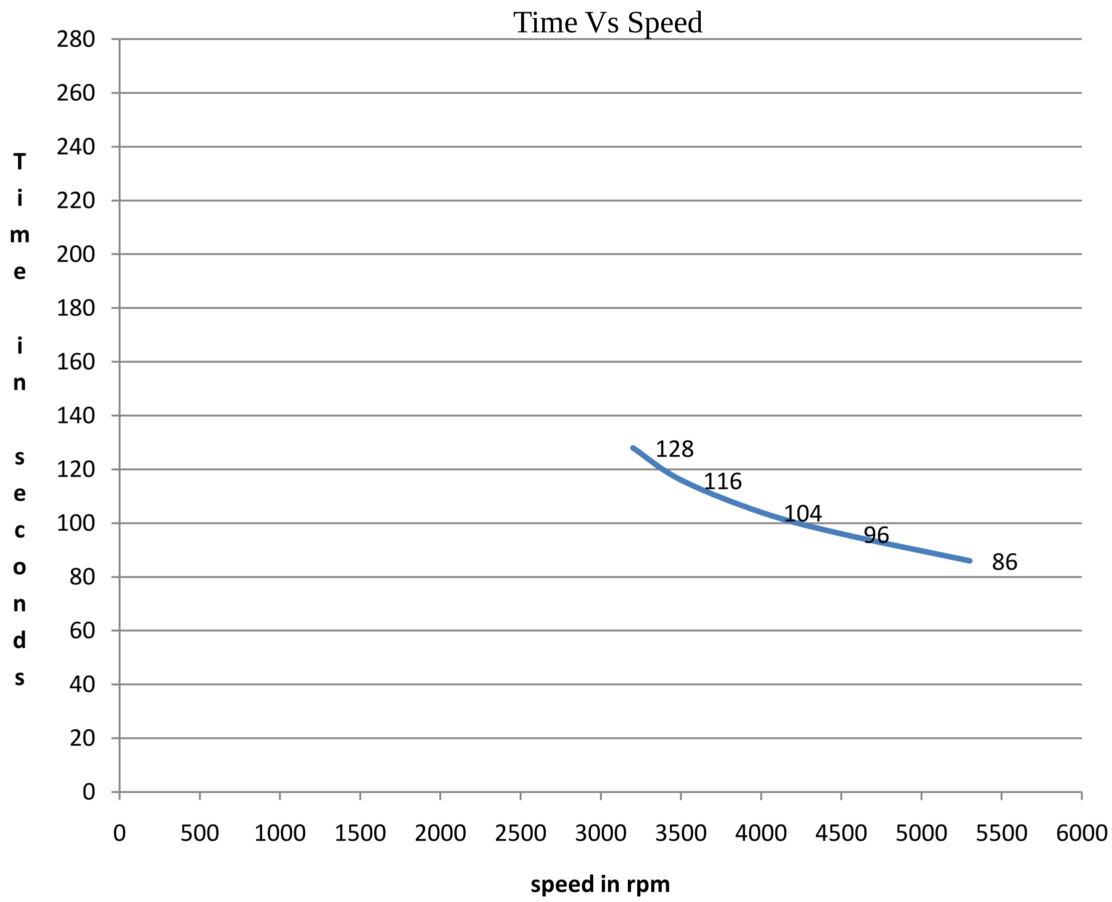
4. RESULTS AND DISCUSSION

4.1 OBSERVATIONS

4.1.1 Using Petrol Only

SL NO.	SPEED IN RPM	TIME IN SECONDS FOR 10 ML PETROL CONSUMPTION
1	3200	128
2	3500	116
3	4000	104
4	4500	96
5	5300	86

Table 4.1 Using Petrol Only



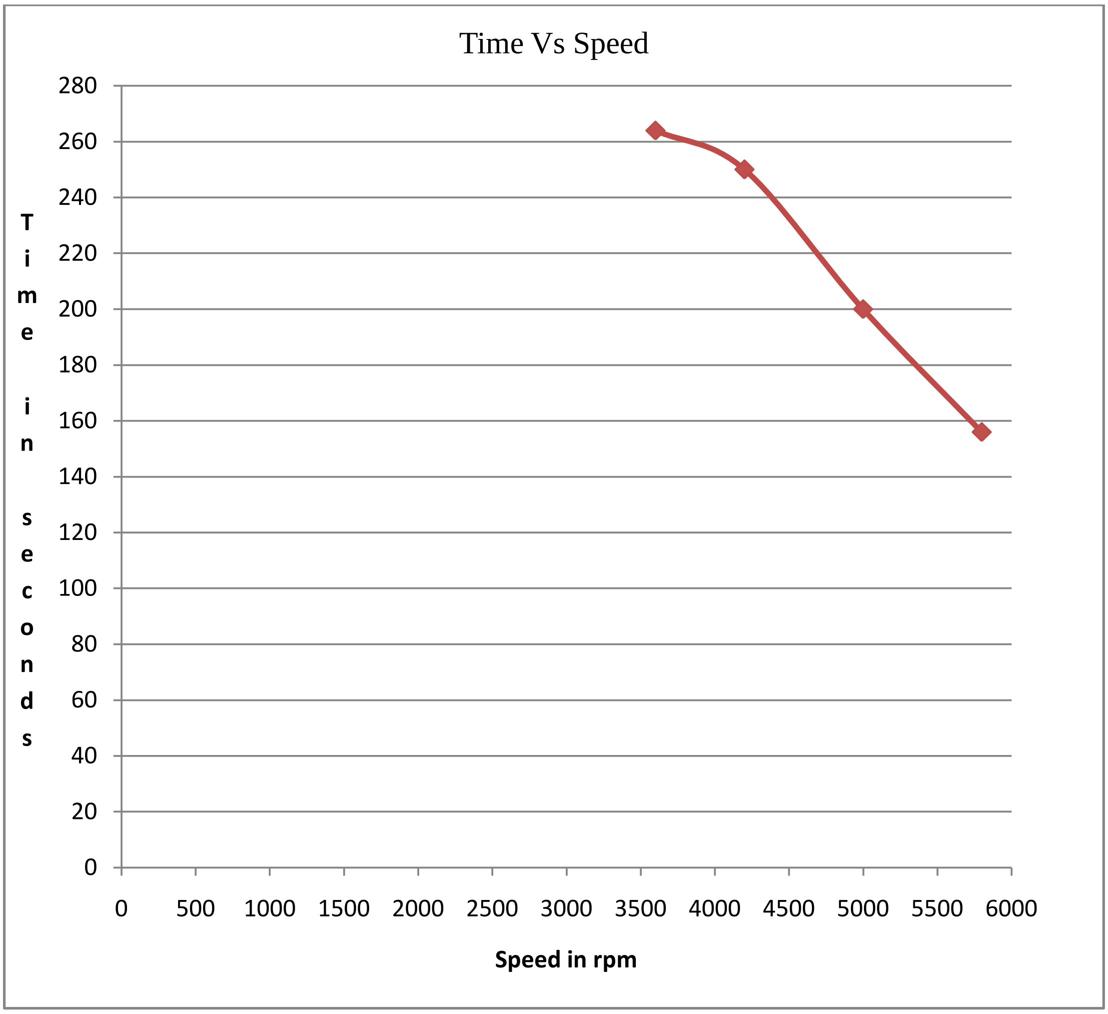
Graph 4.1 Speed Vs time Using Petrol Only

Based on calculations a graph was plotted(x axis- time in sec and y-axis speed of engine in rpm) and fuel consumption for the engine under normal condition was noted. And a graph was obtained showing increase in fuel consumption with increase in rpm .this was also used as the standard for comparison w .r. t other methods using additive (ethanol) and EGR system. Due to increase in rpm more fuel is consumed by the engine resulting in decrease in time for 10mL consumption of fuel. When power demand increases number of stroke per unit time also increases, which results in higher fuel consumption.

4.1.2 Using Petrol And Ethanol

SL NO.	SPEED IN RPM	TIME IN SECONDS FOR 10 ML PETROL CONSUMPTION
1	3600	264
2	4200	250
3	5000	200
4	5800	156

Table 4.2 Using Petrol& Ethanol



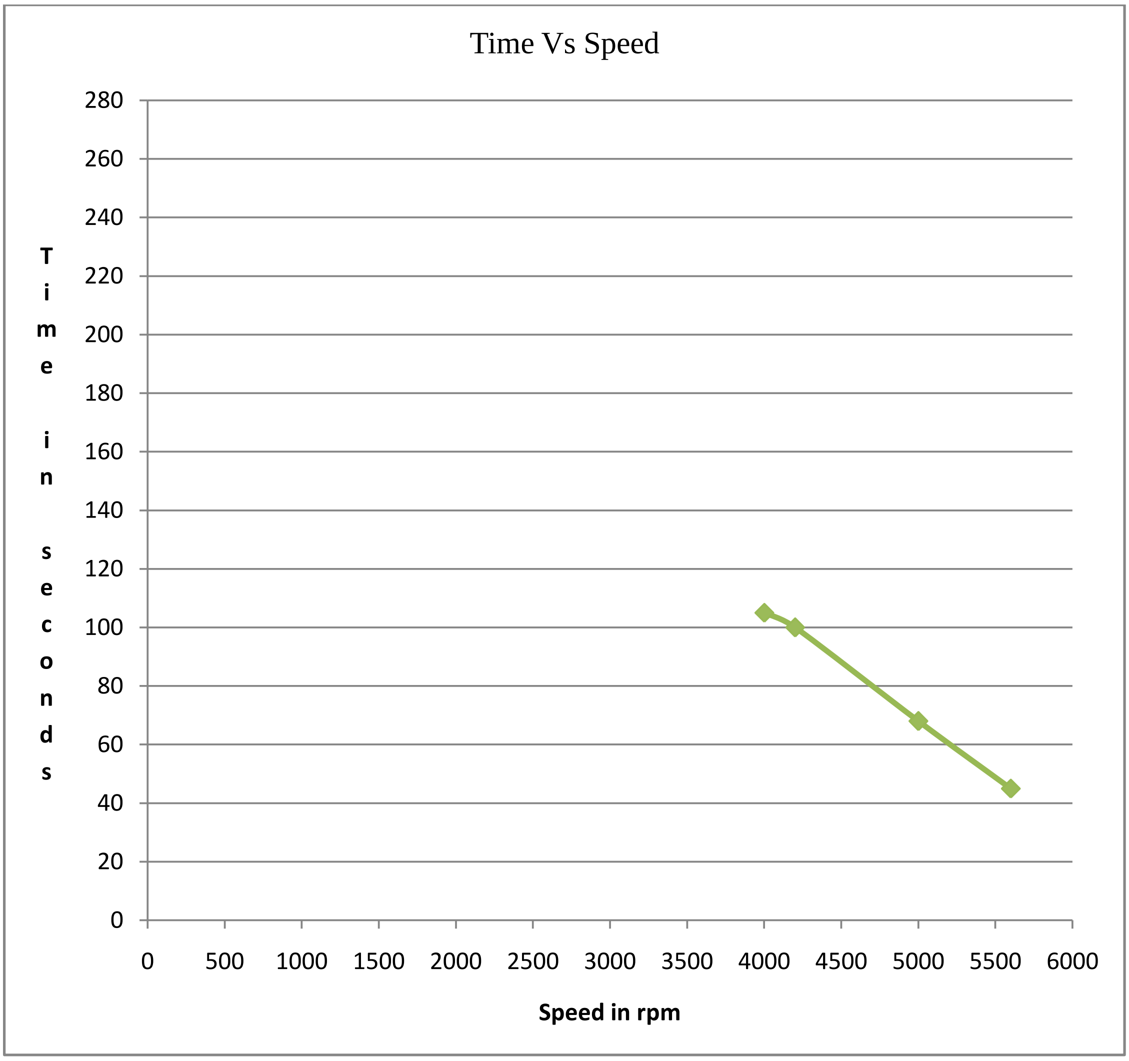
Graph 4.2 Time Vs Speed using Petrol& Ethanol

The same procedure was followed but this time by adding ethanol along with petrol and was found that a similar graph was obtained but the fuel consumption decreased to a large extend as observed from the graph. The increase in efficiency can be noted from the graph as more than 148%. The heat of evaporation of ethanol is higher than that of gasoline, which provides fuel–air charge cooling and increases the density of the charge, and thus higher power output is obtained. With the increase in ethanol percentage, the density of the mixture and the engine volumetric efficiency increases and this causes the increase of power.

4.1.3 Using Petrol ,Ethanol And EGR

SL NO.	SPEED IN RPM	TIME IN SECONDS FOR 10 ML PETROL CONSUMPTION
1	4000	105
2	4200	100
3	5000	68
4	5600	45

Table 4.3 using Petrol,EGR& Ethanol



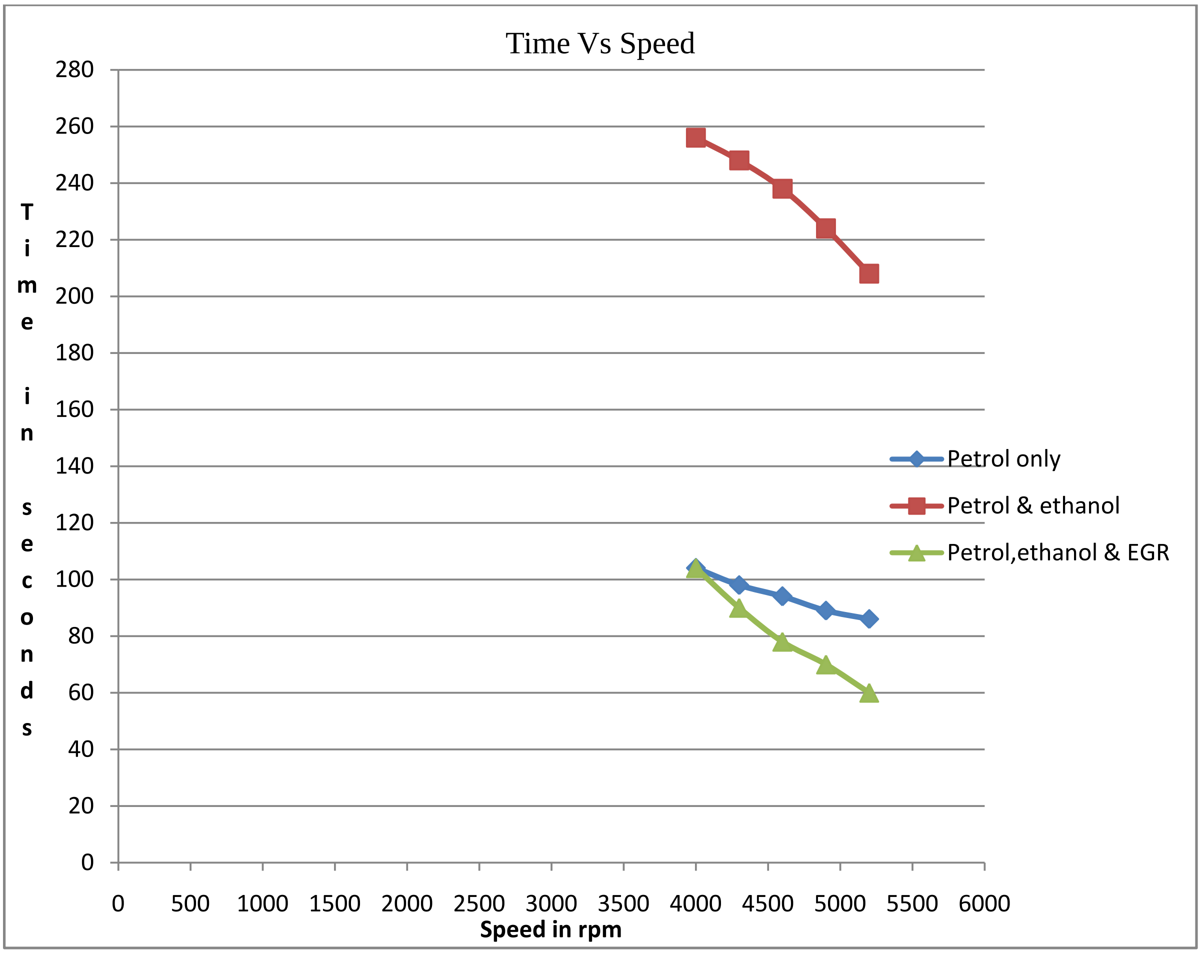
Graph 4.3 Time Vs Speed using Petrol ,EGR& Ethanol

It was found that the graph plotted showed more fuel consumption for higher rpm and the graph plotted shows that there is less fuel economy for the system with ethanol and EGR along with petrol. It was found that ethanol along with petrol will give the desired fuel consumption and it is preferable over this method due to condensation in the EGR. EGR is a well known incylinder method that offers the possibility to decrease temperature during combustion. By increasing re-circulated gases, the EGR replaces some of the inlet air and decreases incylinder trapped oxygen. This shortage of oxygen also affects the flame speed and penetration and slows down the combustion rate causing a low in-cylinder pressure at high levels of EGR.

4.1.4 Comparison Of Fuel Efficiency

Sl No	Speed in rpm	Time for 10ml consumption of fuel in seconds			Increase in efficiency (%)	
		Using petrol only	Using petrol & ethanol	Using petrol, ethanol & EGR	Using petrol & ethanol	Using petrol,ethanol & EGR
1	4000	104	256	104	146.1	0
2	4300	98	248	90	153.06	-8.1
3	4600	94	238	78	153.19	-17.03
4	4900	89	224	70	151.68	-21.34
5	5200	86	208	60	141.86	-30.2

Table 4.4 Comparison Of Fuel Efficiency



Graph 4.4 Time Vs Speed Comparison Of Fuel Efficiency

From the experiment it was found that while using petrol and ethanol efficiency was increased to about 148% from conventional running mode. it was also found that while using ethanol along with EGR efficiency was decreased to about 15% from conventional running mode. The graph plotted can be compared and found that for all the graphs the fuel consumption increases as speed is increased. It was also found that the graph plotted by using petrol and ethanol had promising results. The graph using ethanol and petrol was found to be far above the other two graph plots as ethanol being a good oxidiser helps to give high fuel efficiency and a more efficient time for fuel consumption as per[2].

4.2 SCOPE OF THE PROJECT

The Oxides of Nitrogen (NOx) and smoke emissions are reduced in HCCI engine. But the CO and HC emissions are marginally high when compared with base engine. So, efforts are required to reduce CO and HC emissions. Thus reducing the CO and HC emissions EGR efficiency can be improved. Further improvement in EGR system auto ignition can be achieved. Combustion chamber geometry will benefit the atomization of fuel which leads to better HCCI combustion. The flow characteristics should be studied and the engine geometry should be designed for further improvement in HCCI combustion. It is felt that there is a requirement to investigate and analyze the flow characteristics either by using multi-dimensional models theoretically or experimentally. This is going to be very helpful for the development of future HCCI engine.

5.CONCLUSIONS

From the project it can be concluded that :-

1. Fuel efficiency of the project was increased to about 148% from conventional working condition when ethanol was used along with as the heat of evaporation of ethanol is higher than that of gasoline, which provides fuel–air charge cooling and increases the density of the charge, and thus higher power output is obtained . With the increase in ethanol percentage, the density of the mixture and the engine volumetric efficiency increases and this causes the increase of power.
2. Fuel efficiency was found to be decreased by 14% from conventional working condition when ethanol and EGR systems were used along with petrol as the EGR replaces some of the inlet air and decreases in cylinder trapped oxygen. This shortage of oxygen also affects the flame speed and penetration and slows down the combustion rate causing a low in-cylinder pressure at high levels of EGR and this is why auto ignition was not obtained.
3. Further development of a series hybrid system which transfers energy to the wheel drive from the engine via generator, battery and motor system will help effective transmission of power with less loss of efficiency.

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