Performance of Diesel Engine using HHO gas (Brown gas)

Chapter 1

INTRODUCTION

1.1 General

Fossil fuels (i.e., petroleum, natural gas and coal), which meet most of the world's energy demand today, are being depleted rapidly. Also, their combustion products are causing global problems, such as the greenhouse effect, ozone layer depletion, acid rains and pollution, which are posing great danger for our environment, and eventually, for the total life on our planet. Many engineers and scientists agree that the solution to all of these global problems would be to replace the existing fossil fuel system with the clean hydrogen energy system. Hydrogen is a very efficient and clean fuel. Its combustion will produce no greenhouse gases, no ozone layer depleting chemicals, and little or no acid rain ingredients and pollution. Hydrogen, produced from renewable energy (solar, wind, etc.) sources, would result in a permanent energy system which would never have to be changed.

Fossil fuels possess very useful properties not shared by non-conventional energy sources that have made them popular during the last century. Unfortunately, fossil fuels are not renewable. In addition, the pollutants emitted by fossil energy systems (e.g. CO, CO2, CnHm, SOx, NOx, radioactivity, heavy metals, ashes, etc.) are greater and more damaging than those that might be produced by a renewable based hydrogen energy system (Winter CJ. 1987). Since the oil crisis of 1973, considerable progress has been made in the search for alternative energy sources. A long term goal of energy research has been the seek for a method to produce hydrogen fuel economically by splitting water using sunlight as the primary energy source. Much fundamental research remains to be done. Lowering of worldwide CO_2 emission to reduce the risk of climate change (greenhouse effect) requires a major restructuring of the energy system. The use of hydrogen as an energy carrier is a long term option to reduce CO_2 emissions.

However, at the present time, hydrogen is not competitive with other energy carriers. Global utilization of fossil fuels for energy needs is rapidly resulting in critical environmental problems throughout the world. Energy, economic and political crises, as well as the health of humans, animals and plant life, are all critical concerns. There is an urgent need of implementing the hydrogen technology. A worldwide conversion from fossil fuels to hydrogen would eliminate many of the problems and their consequences. The production of hydrogen from non-polluting sources is the ideal way.

Solar hydrogen is a clean energy carrier. Hydrogen obtained from solar energy is ecologically responsible along its entire energy conversion chain. Energy stored in hydrogen would be available at any time and at any place on Earth, regardless of when or where the solar irradiance, the hydropower, or other renewable sources such as biomass, ocean energy or wind energy was converted. Solar hydrogen is a clean energy carrier. It makes solar energy as storable and transportable as oil and natural gas are by nature, but without the burden of their negative environmental impact. Solar hydrogen combines the advantages of hydrocarbons (storability and transportability) with the advantages of solar energy (ecological acceptability, renewability and low risk). Solar hydrogen has no need for the carbon atom, which makes the hydrocarbons almost infinitely storable at room temperatures, but is also the reason for their negative ecological impact.

Technology developments have created several challengers to the gasoline powered, internal combustion engine (ICE) vehicle. Short of some wonderful new technology emerging, the evolving gasoline fuelled ICE will continue to be the choice of consumers and automakers. Even with regulatory pressure, it is doubtful that any technology would displace the gasoline fuelled ICE—at least not by 2020 or 2030. Perhaps, the only market signal that would make a new technology more attractive would be a large increase in gasoline prices. For example, $3 per litre gasoline would encourage people to buy diesel or ethanol powered vehicles, perhaps in conjunction with a hybrid-electric technology. At $1.50 per litre, these alternatives have a tiny market share. The search for new technologies and fuels is driven by regulators, not the marketplace.

Hydrogen has long been recognized as a fuel having some unique and highly desirable properties, for application as a fuel in engines. It is the only fuel that can be produced entirely from the plentiful renewable resource water, though through the expenditure of relatively much energy. Its combustion in oxygen produces uniquely only water but in air it also produces some oxides of nitrogen. These features make hydrogen an excellent fuel to potentially meet the ever increasingly strict environmental controls of exhaust emissions from combustion devices, including the reduction of greenhouse gas emissions.

The use of hydrogen as an engine fuel has been attempted on very limited basis with varying degrees of success by numerous investigators over many decades, and much information about their findings is available in the open literature. However, these reported performance data do not display consistent agreement between various investigators. There is also a tendency to focus on results obtained in specific engines and over narrowly changed operating conditions. Moreover, the increasingly greater emphasis being placed on the nature of emissions and efficiency considerations often makes much of the very early work fragmentary and mainly of historical value. Obviously, there is a need to be aware of what has been achieved in this field while focusing both on the attractive features as well as the potential limitations and associated drawbacks that need to be overcome for hydrogen to become a widely accepted and used fuel for engine applications. Also, there is a need to indicate practical steps for operating and design measures to be developed and incorporated for hydrogen to achieve its full potential as an attractive and superior engine fuel.

A diesel engine (also known as a compression-ignition engine) is an internal combustion engine that uses the heat of compression to initiate ignition to burn the fuel that has been injected into the combustion chamber. This is in contrast to spark-ignition engines such as a petrol engine (gasoline engine) or gas engine (using gaseous fuel as opposed to gasoline), which uses a spark plug to ignite an air-fuel mixture. The engine was developed by German inventor Rudolf Diesel in 1893.

The diesel engine has the highest thermal efficiency of any regular internal or external combustion engine due to its very high compression ratio. Low-speed diesel engines (as used in ships and other applications where overall engine weight is relatively unimportant) can have a thermal efficiency that exceeds 50%.

Diesel engines are manufactured in two-stroke and four-stroke versions. They were originally used as a more efficient replacement for stationary steam engines. Since the 1910s they have been used in submarines and ships. Use in locomotives, trucks, heavy equipment and electric generating plants followed later. In the 1930s, they slowly began to be used in a few automobiles. Since the 1970s, the use of diesel engines in larger on-road and off-road vehicles in these increased. As of 2007, about 50% of all new car sales in Europe are diesel.

The world's largest diesel engine is currently a Wärtsilä-SulzerRTA96-C Common Rail marine diesel of about 84,420 kW.

The diesel internal combustion engine differs from the gasoline powered Otto cycle by using highly compressed hot air to ignite the fuel rather than using a spark plug (compression ignition) rather than spark plug. In the true diesel engine, only air is initially introduced into the combustion chamber. The air is then compressed with a compression ratio typically between 15:1 and 22:1 resulting in 40-bar (4.0 MPa;580 psi) pressure compared to 8 to 14 bars (0.80 to 1.4 MPa) (about200 psi) in the petrol engine. This high compression heats the air to550 °C (1,022 °F). At about the top of the compression stroke, fuel is injected directly into the compressed air in the combustion chamber. This may be into a (typically steroidal) void in the top of the piston oar *pre-chamber* depending upon the design of the engine. The fuel injector ensures that the fuel is broken down into small droplets, and that the fuel is distributed evenly. The heat of the compressed air vaporizes fuel from the surface of the droplets. The vapour is then ignited by the heat from the compressed air in the combustion chamber, the droplets continue to vaporise from their surfaces and burn, getting smaller, until all the fuel in the droplets has been burnt. The start of vaporisation causes a delay period during ignition and the characteristic diesel knocking sound as the vapour reaches ignition temperature and causes an abrupt increase in pressure above the piston. The rapid expansion of combustion gases then drives the piston downward, supplying power to the crankshaft. As well as the high level of compression allowing combustion to take place without a separate ignition system, a high compression ratio greatly increases the engine's efficiency. Increasing the compression ratio in a spark-ignition engine where fuel and air are mixed before entry to the cylinder is limited by the need to prevent damaging pre-ignition. Since only air is compressed in a diesel engine, and fuel is not introduced into the cylinder until shortly before top dead centre (TDC), premature detonation is not an issue and compression ratios are much higher.

Chapter 2

LITERATURE SURVEY

2.1 Use of H_2 as IC engine fuel

In the early years of the development of internal combustion engines hydrogen was not the “exotic" fuel that it is today. Water splitting by electrolysis was a well-known laboratory phenomenon. Otto, in the early 1870s, considered a variety of fuels for his internal combustion engine, including hydrogen. He rejected gasoline as being too dangerous. Later developments in combustion technology made gasoline safer.

Most early engine experiments were designed for burning a variety of gases, including natural gas and propane. When hydrogen was used in these engines it would backfire. Since hydrogen burns faster than other fuels, the fuel-air mixture would ignite in the intake manifold before the intake valve could close. Injected water controlled the backfiring. Hydrogen gave less power than gasoline with or without the water.

2.2 During World War

During World War I hydrogen and pure oxygen were considered for submarine use because the crew could get drinkable water from the exhaust. Hydrogen was also considered for use in powering airship engines. The gas used for buoyancy could also be used for fuel. Even if helium were used to provide lift, hydrogen gas could be used to supply additional buoyancy if stored at low pressure in a light container. It was Rudolf A. Erren who first made practical the hydrogen-fueled engine in the 1920s and converted over 1,000 engines. His projects included trucks and buses.

After World War II the allies discovered a submarine converted by Erren to hydrogen power. Even the torpedoes were hydrogen powered. In 1924 Ricardo conducted the first systematic engine performance tests on hydrogen. He used a one cylinder engine and tried various compression ratios. At a compression ratio of 7:1, the engine achieved a peak efficiency of 43%. At compression ratio of 9.9:1, Burn stall obtained an efficiency of 41.3% with an equivalency ratio range of 0.58-0.80.

After World War II, King found the cause of preignition to be hot spots in the combustion chamber from the high temperature ash, the residue from burned oil and dust. He traced backfire to high flame velocity at high equivalency ratios. M.R. Swain and R.R. Adt at the University of Miami developed modified injection techniques with a 1,600 cm^3 Toyota engine with a compression ratio of 9:1. The Illinois Institute of Technology converted a 1972 Vega using a propane carburettor. Converting to propane fuel utilizes similar technology as hydrogen. Roger Billings, in collaboration with Brigham Young University, entered a hydrogen-converted Volkswagen in the 1972 Urban Vehicle Competition. The vehicle won first place in the emissions category over 60 other vehicles even though the peak emissions were greater than for other hydrogen powered vehicles elsewhere. Nitrous oxides exceeded levels obtained by other experimenters using direct injection.

2.3 Experiments on hydrogen fuelled engine in India.

The Indian Institute of Technology tested spark ignition engines converted to hydrogen and has come to the following conclusions: Hydrogen permits a wide range of fuel-air mixtures. Very little throttling is needed. The fuel-air ratio and the amount of fuel are varied instead. Conversion requires higher compression ratios like up to 11:1. Hydrogen is 30 to 50% more efficient than gasoline. The Indian researchers also reached some conclusions regarding the use of hydrogen in addition to diesel fuel in diesel engines. They reduced the compression ratios from 16.5:1 to 14.5:1. Because of hydrogen's high rate of combustion only a small amount should be used mixed with diesel fuel. A high ignition temperature is necessary: 585°C. The more hydrogen is added to the fuel mix the lower is the level of toxic emissions.

The Billings Energy Corporation in Independence, Missouri, converted a U.S. postal Jeep to hydrogen hydride. On gasoline it got 3.9 km/litre. The hydrogen fuel consumption is 4.9 km/litre per gasoline energy equivalent. This was an improvement of 24%. A special gaseous carburettor was used. High flame speed and low ignition energy required narrowing the spark gap. Problems of rusting and pitting on the sparkplug tip developed. Billings replaced the plugs with Champion stainless steel plugs to eliminate the problem. Rusted plug tips can cause preignition through the valves (backfire). Since the firing rate was faster, they had to change the ignition timing on the inline six-cylinder engine. The researchers added a water injection system to lower the combustion temperature and nitrous oxide production. The ratio was 4:1, by weight, of water to hydrogen. Daily fuel consumption was 1.4 kg of hydrogen and 5.4 kg of water. Water was injected as a fine mist directly into the manifold of the engine. This reduced backfiring into the manifold and boosted power.

Robert Zweig converted a pickup truck to hydrogen power in 1975. It has been running ever since. He solved the backfiring problem by using an extra intake valve to admit hydrogen separately from air. It is a simple, elegant vehicle that uses compressed hydrogen. The American Hydrogen Association displays the Zweig hydrogen pickup trucks in public exhibits. The Brookhaven National Laboratory converted a Wankel (rotary) engine to hydrogen. It worked better with hydrogen than conventional engines because its combustion chamber enhances the emission of hydrocarbon pollutants. Mazda has converted one of their rotary engine cars to run on hydrogen. The unique design of the rotary engine keeps the hydrogen and air separate until they are combined in the combustion chamber.

In experiments in 1980 with a diesel engine converted to run on 100% hydrogen, the U.S. Bureau of Mines, in collaboration with EIMCO Mining Machinery, found that the nitrous oxide emissions for hydrogen is one tenth of the amount for the same vehicle on diesel. With hydrogen, the only other emission was water vapour. This is important for vehicles operating in mines and other confined spaces. They mounted a 63.4 kW (85 hp) engine on a 4,500 kg truck. The diesel engine required the addition of spark ignition. Compression alone would not ignite the hydrogen at the reduced compression ratio. They added a turbocharger to increase the density of the incoming fuel. The fuel induction system provides two intake paths; one for hydrogen and one for air. The fuel and air are kept separate until entering the cylinder to prevent backfiring.

2.4 Hydrogen energy progress X, Proceedings of the Tenth World Hydrogen Energy Conference

The Laboratory of Transport technology (University of Gent, Belgium) has specialized in alternative fuels for the past 10 years or so. Natural gas, LPG, hythane and hydrogen have been the subject of extended research. In a first stage, a Val met 420D engine, a natural aspirated diesel engine with direct injection was converted to a spark ignited engine for the use of hydrogen. This engine was used mainly for the development of a multipoint timed injection system and the study of different types of electromagnetic gas injectors. The tests showed several shortcomings of the then available gas injectors: leakage, unequal response time (opening delay) and low durability. In the meantime however, the research on gaseous injection systems (natural gas, LPG, etc.) has been increased enormously by the specialized companies and these problems are largely solved now.

A second engine, a GM Crusader V8, was then converted for hydrogen use. The first tests were done with a gas carburettor, which allowed testing with hydrogen, natural gas and hydrogen-natural gas mixtures (hyphae). In order to obtain a better control of the combustion process, the engine was then equipped with a sequential timed multipoint injection system. Such an injection system, as applied to liquid fuels (gasoline, liquid LPG, etc.) has several advantages including the possibility to tune the air-fuel ratio of each cylinder to a well-defined value, increased power output and decreased cyclic variation of the combustion process in the cylinders. Timed injection also has an additional benefit for a hydrogen fuelled engine, as it implies a better resistance to backfire (explosion of the air-fuel mixture in the inlet manifold). In nearly all cases, backfire-safe operation implies a limitation of the operation region of the air-fuel mixture on the “rich” side, thus for high load conditions. This restriction is decreased by the use of a multi-point sequential injection system. Direct injection in the combustion chamber, cryogenic storage (liquid hydrogen tank) and pump is even better, but not technically available for mass production. All these advantages are well known. The disadvantage of low pressure sequential gas injection is the low density of the gas. For smaller engines running at high speeds (traction application), the injectors have to deliver a high volume of gas in a very short time. Other problems may arise with the durability of the injectors and possible leaks.

2.5 Hydrogen: Its technology and implications

The German Aerospace Research Establishment (DLR) used cryogenic hydrogen with hybrid mixture formation on a BMW 745i vehicle in a joint effort with BMW. The cryogenic characteristics of hydrogen like high range per tank filling and low amount of mass for storage favour its use together with the cooling effect that occurs during external mixing. Satisfactory achievements were made by hybrid mixture formation, a proper combination of both internal and external mixture formation, in means of power and torque characteristics under steady and intermittent operating conditions.

2.6 Other alternative fuels

The entire surface transport of India is based on petroleum fuel, but its availability is of growing concern. The production of domestic crude has been declining and the transport system has been increasingly dependent on imported crude oil to meet its needs. There is a growing concern that the world may run out of petroleum based fuel resources. All these make it imperative that the search for alternative fuels is taken in right earnest. The alternative fuels aspiring to take the place of petroleum are:

2.6.1 Propane

Liquefied petroleum gas (LPG) consists mainly of propane, propylene, butane, and butylene’s in various mixtures. It is produced as a by-product of natural gas processing and petroleum refining. With propane’s simple molecular composition, propane - fuelled vehicles emit significantly lower levels of carbon monoxide, hydrocarbons and nitrogen oxides than gasoline - fuelled vehicles. The level of air - toxic emissions from propane - fuelled vehicles is also low. According to the National Propane Gas Association, U.S.A., spark plugs from a propane vehicle last from 80,000 to 100,000 miles and propane engines can last two to three times longer than gasoline or diesel engines.

2.6.2 Ethanol

Ethanol (ethyl alcohol, grain alcohol, ETOH) is a clear, colourless liquid with characteristic, agreeable odours. Two higher blends of ethanol, E-85 and E-95 are being explored as alternative fuels in demonstration programs. Ethanol is also made into ether, ethyl tertiary-butyl ether (ETBE) that has properties of interest for oxygenated gasoline and reformulated fuels. The environmental benefits of ethanol include: 10% ethanol blends reduce carbon monoxide better than any other reformulated gasoline blend. Ethanol is a safe replacement for toxic octane enhancers in gasoline such as benzene, toluene and xylene. ETBE lowers gasoline volatility and is, thus, particularly effective in reducing VOC emissions from automobiles.

2.6.3 Methanol

Methanol (CH3OH) is an alcohol fuel. As engine fuels, ethanol and methanol have similar chemical and physical characteristics. Methanol is methane with one hydrogen molecule replaced by a hydroxyl radical. It is produced from natural gas in production plants with 60% total energy efficiency. Methanol can be made with any renewable resource containing carbon such as seaweed, waste wood and garbage.

This is a promising alternative, with a diversity of fuel applications with proven environmental, economic and consumer benefits. It is widely used today to produce the oxygenate MTBE added to cleaner burning gasoline. Cars, trucks and buses running millions of miles on methanol have proven its use as a total replacement for gasoline and diesel fuels in conventional engines... Methanol fuel cells will greatly reduce carbon dioxide emissions for vehicles and virtually eliminate smog and particulate pollution.

2.6.4 Bio diesel

Biodiesel (mono alkyl esters) is a cleaner-burning diesel fuel made from natural, renewable sources such as vegetable oils. Just like petroleum diesel, biodiesel operates in combustion-ignition engines. The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter. It also decreases the solid carbon fraction of particulate matter (since the oxygen in biodiesel enables more complete combustion to CO2), eliminates the sulphate fraction (as there is no sulphur in the fuel), while the soluble, or hydrocarbon, fraction stays the same or is increased. Therefore, biodiesel works well with new technologies such as catalysts (which reduces the soluble fraction of diesel particulate but not the solid carbon fraction), particulate traps, and exhaust gas recirculation (potentially longer engine life due to less carbon).

2.6.5 Electric Fuel

Electricity is unique among the alternative fuels in that mechanical power is derived directly from it, whereas the other alternative fuels release stored chemical energy through combustion to provide mechanical power. Batteries commonly provide electricity used to power vehicles, but fuel cells are also being explored. A large number of various types of batteries are being tested for use in EVs. Some of the technologies being used or evaluated include lead-acid, nickel cadmium, nickel iron, nickel zinc, nickel metal hydride, sodium nickel chloride, zinc bromine, sodium sulphur, lithium, zinc air, and aluminium air. The first benefit of using electric fuel is that you are not polluting the environment. The maintenance costs for EVs are less-EVs have fewer moving parts to service and replace.

2.6.6 HHO Gas

The HHO gas is nothing but the electrolyte form of water. It is also called as oxy-hydrogen or brown gas. It is produced by electrolysis process, where an electrical power source is connected to two electrodes and which are placed in a mixture of water and electrolyte. Oxyhydrogen appears to be a favourable alternative fuel on account of its high specific energy per unit weight, its all-time availability as a component of water, good combustion characteristics and eco-friendly, fast burning and higher flame propagation rates are the attractive features of HHO gas. HHO gas is a mixture of hydrogen and oxygen gases, typically in a 2:1 atomic ratio; the same proportion as water. At normal temperature and pressure, oxyhydrogen can burn when it is between about 4% and 94% hydrogen by volume, with a flame temperature around 2000^0C. Oxyhydrogen will combust (turning into water vapour and releasinging energy which sustains the reaction) when brought to its auto ignition temperature. For a stoichiometric mixture at normal atmospheric pressure, this is about 570^0C(1065^0F). The minimum energy required to ignite such a mixture with a spark is about 0.02mJ. The quantity of heat evolved, according to Julius thomsen, is 34,116 calories for each gram of hydrogen burned. This heat-disturbance is quite independent of the mode in which the process is conducted; but the temperature of the flame is dependent on the circumstances under which the process takes place. It obviously attains its maximum in the case of the firing of pure "oxyhydrogen" gas (a mixture of hydrogen with exactly half its volume of oxygen, the quantity it combines with in becoming water, German Knall-gas). It becomes less when the "oxyhydrogen" is mixed with excess of one or the other of the two reacting gases, or an inert gas such as nitrogen, because in any such case the same amount of heat spreads over a larger quantity of matter.

2.6.7 Performance characteristics of petrol and HHO gas when used as a fuel

The performance of petrol engine with HHO up to 30% of full load, brake thermal efficiency will remain same for both the case (petrol and blended). Beyond this point brake thermal efficiency increase linearly for fuel mixture of petrol and HHO gas. And also up to 30% of full load for both cases the brake thermal fuel consumption increases linearly and reaches maximum value. BSFC decreases more rapidly for fuel mixture of petrol and HHO gas than petrol as a fuel.

By comparing the results of above two cases the mixture of petrol and HHO gas gives better result for higher loads. Since HHO is highly combustible fuel, it ensures the complete combustion of the fuel mixture. Thus it results in the increased speed of the engine and in turn increases the power output.

Chapter 3

PROPERTIES OF HHO GAS

There are many unique and unusual properties that HHO Gas possesses. Below is a list of some of the properties.

- Gas proves to be odourless, colourless and lighter than air.
- In the production of HHO Gas, there is no evaporation process at all, the electric energy used being insufficient for evaporation.
- The variable character of the energy content of HHO Gas is evidence that the gas has a unique structure with a chemical composition including bonds beyond those of valence type.
- HHO Gas does not follow the fundamental PVT law for gases.
- HHO Gas demonstrates an anomalous adhesion to gases, liquids and solids. HHO Gas bonds to gaseous fuels (such as natural gas, magnegas fuel, and others) and also to liquid fuels (such as diesel, gasoline, liquid petroleum, and others).
- Santilli describes the creation of the gaseous and combustible HHO from distilled water at atmospheric temperature and pressure via a process structurally different than evaporation or separation, which suggests the existence of a new form of water.
- HHO is described to have the structure H-O-H where represents the new magnecular bond and the conventional molecular bond. The transition from the conventional H-O-H configuration to the new H-O-H species is explained as being a change of the electric polarization of water caused by the electrolyzes.

Chapter 4

PRODUCTION OF HYDROGEN

Hydrogen is not a fuel that occurs free in nature like fossil fuel. Primary source of energy like solar, nuclear or hydro-electric is necessary to separate it from original combined state. The following methods are considered suitable for hydrogen production:

4.1Electrolysis of water

In this method, electrical energy is used to break water into H_2 and O_2. In principle, an electrolysis cell consists of two electrodes, commonly flat metal or carbon plates, immersed in an aqueous conducting solution called the electrolyte.

Figure 4.1 Electrolysis Process

A source of DC voltage connected to the electrodes so that an electric current flows through the electrolyte from anode to cathode. As a result, water in the electrolyte solution is decomposed into H_2 which is released at the cathode and oxygen at the anode. Since water itself is the poor conductor of electricity an electrolyte like KOH is used increase the electric conduction.

4.2 Thermochemical method

This method is considered potentially most promising. It depends on complex series of interactions between the primary energy, water and some specific chemicals to produce hydrogen at temperatures substantially lower than thermal decomposition. The chemicals used are recyclable. A variety of compounds of iron, iodine, lithium and cadmium are used for the purpose.

4.3 Photobialysis

In this process, action of certain catalyst to produce H_2 from water by use of directs sunlight at ambient temperature. Though, it appears attractive, the present efficiency of production is only 1%.

4.4 Thermal decomposition of water

In this method, heat at high temperature (3000^0C) is used to thermally decompose water into H_2 and O_2.

Chapter 5

BASIC DETAILS OF KIT

The HHO generator (kit) is basically an electrolyte cell. Here the kit used is of simple in construction, whose case (container) is made of PVC pipe and the electrodes are made from copper plate of length 500mm and thickness 1mm.The 500mm length copper plate is cut into pieces such that two equal lengths plate are of 250mm respectively. The lengths of both plates are of 250mm respectively and the plates are separated from each other by means of an insulator. Now these arrangements are placed inside a case (container) of diameter 150mm and it's both sides are sealed with end caps (PVC). The upper end cap houses the electrode terminals and also a hole for HHO gas outflow. The lower end cap has a hole for inlet of electrolyte solution. The electrode connections are made in such a way that the small part of the electrode is projected outwards so the melting of the connection between the electrode and the connection is eliminated.

In the electrolysis process the oxygen is generated at anode & hydrogen is generated at cathode. A small free space at the top of the cylinder will allow the gases to mix together. The HHO gas generated from the kit is supplied to the engine. A hole at 30degrees is drilled at the engine manifold to supply the gas. Since HHO gas is highly inflammable, the gas is passed through the water. The container of water acts as a Back Fire Arrestor. This is for safety reasons. Then the gas is passed through the carburettor to run the engine.

Figure 5.1 Supply of HHO gas to the engine

5.1 Design calculation

Some of the important design calculations are as mentioned below,

5.1.1 Length and diameter of the coils

The length and diameter of the coils depend on the production capacity of kit. We have decided to design this system for 12 Amps current. Following are the design calculation for determining the length and diameter of coils.

Design current - 12 Amp

Design voltage - 13.5volts

However in our design, the length and diameter of the copper wire are 2500mm and 1mm respectively. The length of coils (i.e. both electrodes) is 300mm. The dimensions are selected such that to get the optimum results based on both power consumption as well as HHO gas liberation.

5.2 Features of kit

Some of the features of kit are as given below,

5.2.1 Water temperature

The output voltage of battery or an alternator of a vehicle depends on the engine speed i.e.

between 12 volts and 13.8 volts. If the source of power supply to the kit is car battery, the voltage and the current to the kit will always be fluctuating due to the varying engine speed. The amount of gas produced in the kit depends on the voltage applied to the system i.e. at 12 volt the Hydroxyl production will be less however at 13.8 volts the Hydroxy production will be at peak.

Similarly when the water is cold the voltage required to break the water molecules is around 2 volts. The voltage required to break the water molecules decreases as the water temperature of water increases, as this reduces the resistance. In the kit i.e. reduction in the voltage drop due to lower of resistance. At this point of time there is an additional voltage available at set of electrodes, which further heats up the water.

5.2.2 Efficiency of kit

As per the Faradays law thumb rule around 3.24 watts energy is required to produce 1 lap of gas per hour. The kit is producing 1 lpm at 13.8 volts and 12 amps i.e. 165 watts

As per our experiment the most efficient water temperature to operate a kit is between 45-55 deg centigrade. At this stage the production of the Hydroxy is at peak.

5.2.3 NaOH Concentration

In most of the cells, it is required to increase the concentration of the solution on time to time basis. However in this kit, a mesh is fixed just above the coils to hold the KOH foams coming out with the Hydroxy produced in the system. Cost of KOH is also high (nearly ten times of NaOH).

Due to these problems we started to use NaOH solution. This NaOH produces fewer fumes. So there is no problem of reduction in concentration.

5.2.4 Water level indicator

The water level indicator is made using transparent 10mm diameter tube. These components are jointed as leak proof joint on the outer case. This indicator also provides the provision for water topping up.

5.2.5 Fire arrestor

HHO gas is a highly combustible fuel. In order to protect the kit from the back fire produced from the engine the fire arrestors are used. It is a simple method in which, instead of directly supplying HHO gas to the engine it is made to flow through a container containing water. Such that even though the gas catches fire it won't reach the kit.

5.3 Design consideration for kit

The following are the design consideration for a HHO generating kit

- Compact in size
- Suitable for long operation
- Energy efficient
- Safe
- Easy to operate and maintenance free
- Leak proof
- Affordable Price

Chapter 6

PRODUCTION OF HHO GAS

In the project we have considered a simple method to produce HHO gas i.e. “Electrolysis” In this method when a constant current is supplied to an electrolyte solution in a HHO generating kit, the water gets split into Hydrogen gas and Oxygen gas. The Hydrogen gas is generated at cathode (negative electrode) and Oxygen gas generated at anode (positive electrode). Since the HHO gas generator has a single outlet passage for gas, the Hydrogen and oxygen gas generated at their respective electrode are made to flow through this passage. This mixture of these gases is collectively called as oxyhydrogen gas or HHO gas. The HHO gas has the same combustible property as that of Hydrogen gas.

6.1 Preparation of electrolyte solution

Generally the electrolyte solution is prepared by mixing a known quantity of solvent with a known quantity of electrolyte. Here the solvent being used is distilled water and the electrolyte may be either Potassium hydroxide (KOH) or Sodium hydroxide (NaOH).

In order to find the best solution among NaOH and KOH, a small experiment is conducted in which two electrolyte solution are prepared, one consisting of NaOH as an electrolyte and another KOH as an electrolyte. The amount of electrolyte used in both the solution is same. A constant current (DC) is supplied to both the electrolyte solution. Then the amount of gas generated per time i.e. discharge is noted and tabulated. This is repeated for various concentration of electrolyte solution and the readings are tabulated as shown in table 1 and table 2.

Table 6.1for 1 litre of distilled water and KOH

KOH(in grams)	Volume(ml)	Time	Current(A)	Discharge(LPH)
100	600	6min	15	6
175	600	5min	9	7.2
250	**600**	**2min30sec**	**15**	**14.4**

Table 6.2for 1 litre of distilled water and NaOH

NaOH(in grams)	Volume(ml)	Time	Current(A)	Discharge(LPH)
50	600	6min 20sec	6	5.68
150	600	3min38sec	12	9.9
200	600	3min20sec	13	10.8

250	600	3min55sec	12.7	9.19
250	600	7min30sec	6	4.8
250	**600**	**2min57sec**	**16**	**12.2**

Chapter 7

BASIC MEASUREMENTS

The basic measurements which usually should be undertaken to evaluate the performance of an engine are given below

7.1 Speed

One of the basic measurements is that of speed. A wide variety of speed measuring devises are available in the market. They range from a mechanical tachometer to digital and triggered electric tachometer.

The best method of measuring speed is to count the number of revolution in a given time. This gives an accurate measurement of speed. Many engines are fitted with such revolution counter.

7.2 Fuel consumption measurements

The fuel consumption of an engine is measured by determining the volume flow in a given time interval and multiplied it by the specific gravity of the fuel which should be measured occasionally to get an accurate value. Another method is to measure the time required for consumption of a given mass of fuel.

Accurate measurement of fuel consumption is very important in engine testing work.

The two basic types of fuel measuring methods are

- ❖ Volumetric type
- ❖ Gravimetric type

7.2.1 Volumetric type flow meters

- Burette method
- Automatic burette flow meter
- Four piston flow meter
- Turbine flow meter

7.2.2 Gravimetric type flow meter

The efficiency of the engine is related to the kg of fuel which are consumed and not the number of litres. The method measuring volume flow and then correcting it for specific gravity variation is quite convent and inherently limited in accuracy. Instead if the weight of the fuel consumed is directly measured a great improvement in accuracy and cost can be obtained.

The gravimetric type of system which are commercially available

- Four orifice flow meter
- AVL fuel consumption meter

In this project burette method has been used. It is a simplest method of measuring volumetric fuel consumption. It uses a glass burette having bulbs of known volume and having the mark on each side of the bulb. Time taken by the engine to consume this volume is measured by stop watch. Volume divided by time will give the volumetric flow rate. In order to avoid the error in sighting the fuel level against the mark on the burette photocells are used usually such arrangement are made automatically.

7.3 Measurement of air consumption

The diet of engine consist air and fuel. For finding out the performance of the engine accurate measurement both is essential. In IC Engine the satisfactory is measurement of air consumption is quite difficult because the flow is pulsating due to cyclic nature of the engine and because air is compressible fluid. Therefore, the simple method of using an orifice in the induction pipe is not satisfactory since the reading will be pulsating and unreliable.

The methods used for air measurement are

- Air box method
- Viscous flow air meter

This project uses an air box method to determine the air consumption of the engine.

The orifice method can be used pressure pulsation could be damped out by some means. The usual method of damping out pulsation is to fit air box of suitable volume (500 to 600 times the swept volume in the single cylinder engine) to the engine with an orifice in the side of the box remote from the engine.

7.4 Measurement of Brake power

Power developed by the engine at the shaft output is known as brake power. It denoted by BP and expressed in kW or Watt.

Brake power is always lesser than indicated power.

Measurement of the brake power is one of the important measurements in the test schedule of the engine. It involves the determination of the torque and angular speed of the engine output shaft. This torque measurement devises is called dynamometer.

Dynamometer is boldly classified into two types

- Absorption dynamometer
- Transmission dynamometer

7.4.1 Absorption dynamometer

This dynamometer measure and absorbs the power output of the engine to which they are coupled. The power absorbed in is usually dissipated as heat by some means. The types of absorption dynamometer are

- Prony brake
- Rope brake
- Belt brake
- Hydraulic dynamometer
- Eddy current dynamometer
- Swinging field dc dynamometer

7.4.2 Transmission dynamometer

In transmission dynamometer the power is transmitted to the load coupled to the engine after it is indicated on some type of scale. These are also called as torque meter. This project uses an absorption type of dynamometer (belt brake type). It consists of flat belt held around the

circumference of the drum attached to the output of the engine. The both end of the belt is connected to the spring gauge. The power is absorbed in friction between the belt and drum. Therefore the drum requires to cooling. Belt brake is cheap and easily constructed but not very accurate because of changing in the frictional coefficient of the belt with the temperature.

BP = (2πNT) / 60000 kW ……………………..(7.1)

Where, T=torque developed due to net load on the engine, Nm

❖ **Mean effective pressure (MEP):**

It is defined as hypothetical pressure acting on the piston throughout the power stroke. It is denoted by P_m.

P_m= Net area of indicated diagram in mm^2 / (length of indicator diagram* spring constant).

❖ **Indicated power:**

It is the total power actually developed on the piston of the engine.

$IP = (P_m * LAN) / 60000$ W ……………... (7.2)

Where, P_m=mean effective pressure, N/m^2

L=stroke length

A=cross section area of the cylinder, m^2

N=revolution of crank shaft per minute (rpm).

❖ **Friction power:**

The difference between the indicated power and brake power is known as friction power. It is denoted by FP and expressed in kW or Watt.

FP=IP-BP ………… (7.3)

❖ **Total fuel consumption (TFC) = (5 * specific gravity * 3600) / (1000 * time) Kg/hr** ……...….(7.4)

❖ **Brake specific fuel consumption (BSFC)**

BSFC= TFC / BP …………. (7.5)

❖ **Brake thermal efficiency (η_{bth}) = BP * 3600 / TFC *CV** ………… (7.6)

Where, CV = calorific value of the fuel.

Where, p_a = density of air, kg/m^3

V_a = actual volume of the cylinder, m^3

$\rho_a = P_a/(R*T_a)$ ……………(7.7)

Where, P_a = atmospheric pressure, N/m^2

R = real gas constant, 287, kJ/kg K

T_a = atmospheric temperature, K

- **Actual volume** $Va = Cd * \alpha_0 * \sqrt{2 * \Delta p * \rho a}$ **… ……..(7.8)**
- **Swept volume (V_s) = (πD^2* Ln) / 4** **………..(7.9)**

Where, D = bore diameter, m

L = stroke length, m

n = N/2 for 4-stroke engine

- **Volumetric efficiency:** It is defined as the ratio of volume flow rate of air into intake system to the rate at which the volume is displaced by the system.

$\eta_{vol} = v_a / v_s$ **…………………….(7.10)**

Where, Va = volume of the cylinder, m^3

V_s = swept volume, m^3

Chapter 8

DESCRIPTION OF TEST RIG

8.1Engine

The engine used in this project is 4-stroke single cylinder diesel engine (kinloskar)
Engine specification:

Type: 4-stroke water cooled.

- Cylinder: single
- BHP: 5HP
- RPM: 1500RPM
- Fuel: diesel
- Bore: 80mm
- Stroke length: 110mm
- Orifice diameter: 32.3mm
- Compression ratio: 16:1

- Brake drum diameter: 0.32m
- Weight of hanger W_1: 1kg
- Co-efficient of discharge: 0.62
- Specific gravity of diesel: 0.8275
- Calorific value of diesel: 45357KJ/Kg K
- Specific heat of exhaust gases: 1.005KJ/Kg K
- Specific heat of cooling water: 4.187KJ/Kg K

8.2 Dynamometer (mechanical type)

It is a simple device used for measuring brake power of an engine. It consists of a flat belt of 5mm thickness and 100mm width wound around the rotating drum of 330mm of diameter, attached to the shaft of 30mm [diameter, which is connected to the engine out put through chain drive. The both ends of the flat belt is connected to the spring gauge, it consists of 0 to 100 kg of graduations. The load is applied on the drum by using nut and bolt arrangement.

8.3 Manometer (U-tube)

It consists of a U tube filled partially with water. One end of the tube is connected to air drum to measure inside the drum and another led to measure atmospheric pressure.

8.4 Burette

It is a glass tube with graduation. This is used to measure the fuel consumption by the engine. It is connected in between fuel tank and injector.

8.5 Digital RPM indicator

It consists of a digital display with a sensor, which measures the revolution of the output shaft.

8.6 Air drum

It is a cylindrical drum of 550mm length and 300mm diameter, with two passages. One end is connected to the engine through intake manifold other end is free to absorb atmospheric air. The intake air from atmosphere is purified using filter present in the intake passage.

8.7 C-frame

The base of the test rig is made of C-section steel frames. The width of the frame is 80mm and the height is 30mm. Thickness of frame is 5mm.

Chapter 9

DESIGN CALCULATION

9.1 Brake dimensions

Intake Drum Diameter =32cm

Radius R=16cm

BHP= (2πNT)/4500

Where N= speed in rpm

T= W_{max}R

Where T=torque

W_{max}= maximum load caring capacity of engine

R= brake drum radius

9.1.1To find Maximum Load

W_{max}=4500*BHP/ (2π*N*R)

=4500*5/(2π*1500*0.16)

=14.92Kg

∴Maximum Load for the engine, $\boldsymbol{W_{max}}$**=14.92Kg**

Chapter 10

CALCULATIONS

Referring to table 10.1

For load,W =13kg

Brake Power, B.P = $\frac{(2\pi NWR*9.81)}{60000}$, kW

Where,

N is speed in RPM

W is load in kg

R is radius of brake drum in meters

BP = $\frac{(2\pi*1500*13*0.16*9.81)}{60000}$

= 3.2051 kW

Total Fuel consumption, TFC= $\frac{10*\text{ Specific gravity}*3600}{1000*t}$, kg/hr

Where,

Specific gravity of Diesel= 0.8275

T is time for 10cc of fuel consumption in seconds

$$TFC = \frac{10*0.8275*3600}{1000*25}$$

$$= 1.1916 \text{ kg/hr}$$

Friction power, FP= 4.3KW

Indicated power, IP= FP+BP

=4.3+3.2051=7505

Brake specific fuel consumption, $BSFC = \frac{TFC,}{BP}$ kg/kWhr

$$=1.1916/ 1.285657$$

$$= 0.3717 \text{kg/kWhr}$$

Brake mean effective pressure, $BMEP = \frac{BP*0.6}{L*A*(N/2)}$, bar

Where,

L is the stroke length = 80mm = 0.08 m

A is the piston area,$A = \pi r^2$

$=0.08042m^2$

$$BMEP = \frac{3.2051*0.6}{0.08*0.08042*(1500/2)}$$

$$=0.28985 \text{ bar}$$

Brake thermal efficiency, $\eta_{bth} = \frac{BP*3600}{TFC*CV}*100$ %

Where,

CV is the calorific value of fuel = 45357 kJ/kgK

$$\eta_{bth} = \frac{3.2051*3600}{1.1916*45357}$$

$$= 21.3 \%$$

Mechanical efficiency, $\eta_{mech} = \frac{BP}{IP}*100$

Where,BP is the brake power

IP is the indicated power

$=3.2051/7.5051*100$

$=42.705\%$

Indicated thermal efficiency, $\eta_{ind.th} = \frac{IP*3600}{TFC*CV}$

$= (7.505*3600)/(1.1916*45357)$

$= 49.98\%$

10.1 Tabular column

Table 10.1 Performance of engine Using Diesel as a fuel

Sl No.	Load W, (N)	Speed N, (RPM)	Time for 10cc of fuel consumption t, (sec)	Manometer reading h, (m)	B.P (kW)	TFC (kg/hr)	BSFC (kg/kWhr)	BMEP (bar)	η_{bth} %	η_{mech} %
1	0	1500	86	0.052	0	0.346	0	0	0	0
2	4	1500	72	0.056	0.98	0.4137	0.4195	0.0891	18.9	18.65
3	8	1500	47	0.050	1.97	0.633	0.3214	0.1783	24.6	31.4
4	11	1500	31	0.048	2.71	0.96	0.354	0.2452	22.3	38.6
5	13	1500	25	0.049	3.2	1.1916	0.3717	0.2898	21.3	42.70

Table 10.2Using Diesel and HHO gas

Sl No.	Load W, (N)	Speed N, (RPM)	Time for 10cc of fuel consumption t, (sec)	Manometer reading h, (m)	BP (KW)	TFC (kg/hr)	BSFC (kg/kWhr)	BMEP (bar)	η_{bth} %	η_{mech} %	%of diesel saved
1	0	1500	89	0.049	0	0.3347	0	0	0	0	3.2
2	4	1500	73	0.049	0.98	0.408	0.4137	0.0891	19.18	23.00	1.2
3	8	1500	48	0.049	1.97	0.620	0.3145	0.1783	25.20	37.40	2.1
4	11	1500	33	0.047	2.712	0.902	0.3336	0.245	23.84	45.10	6
5	13	1500	31	0.047	3.205	0.9609	0.2998	0.2898	26.47	49.27	19.3

10.2 Graphs

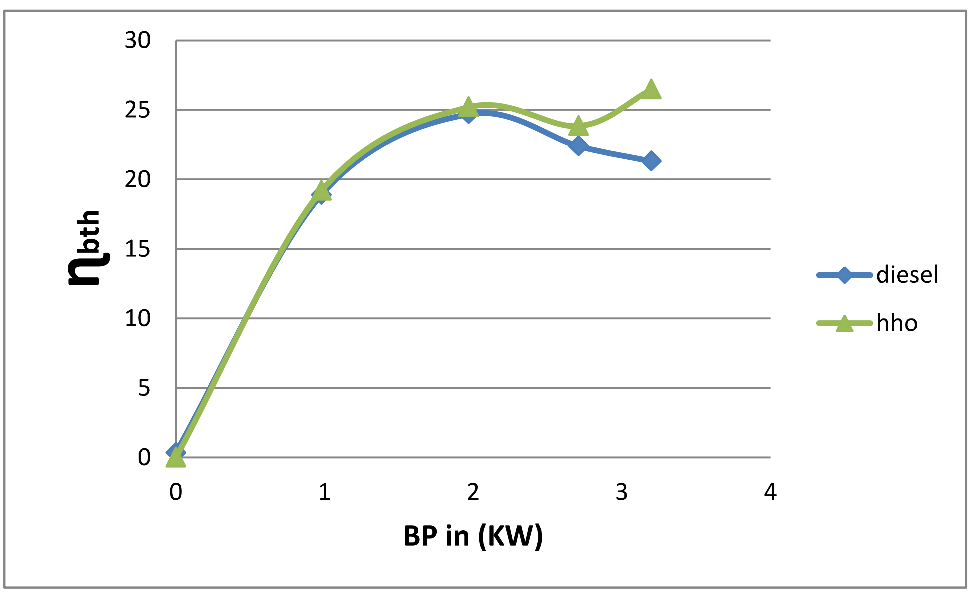

Figure 10.1 Break thermal efficiency v/s Brake power

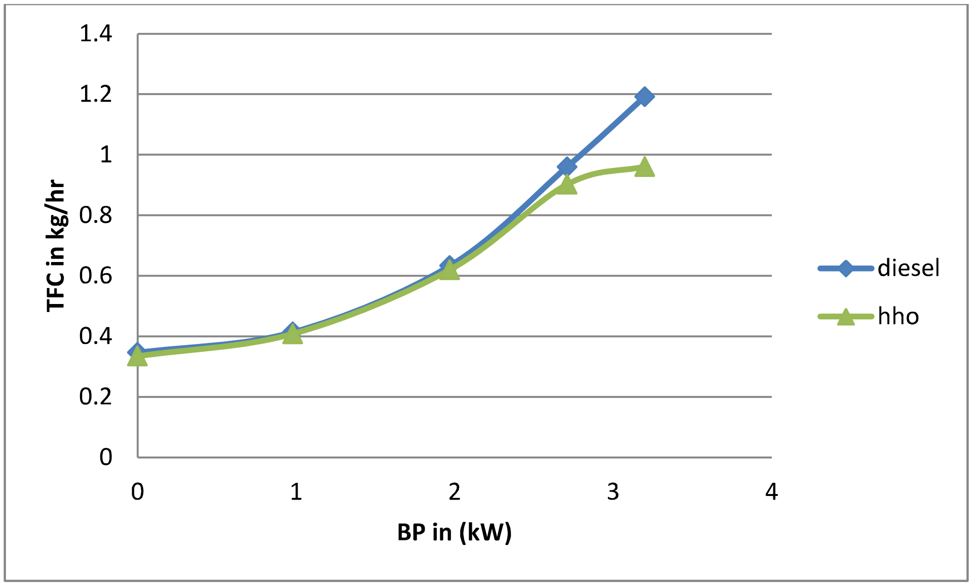

Figure 10.2 Total fuel consumption (TFC) v/s Brake power

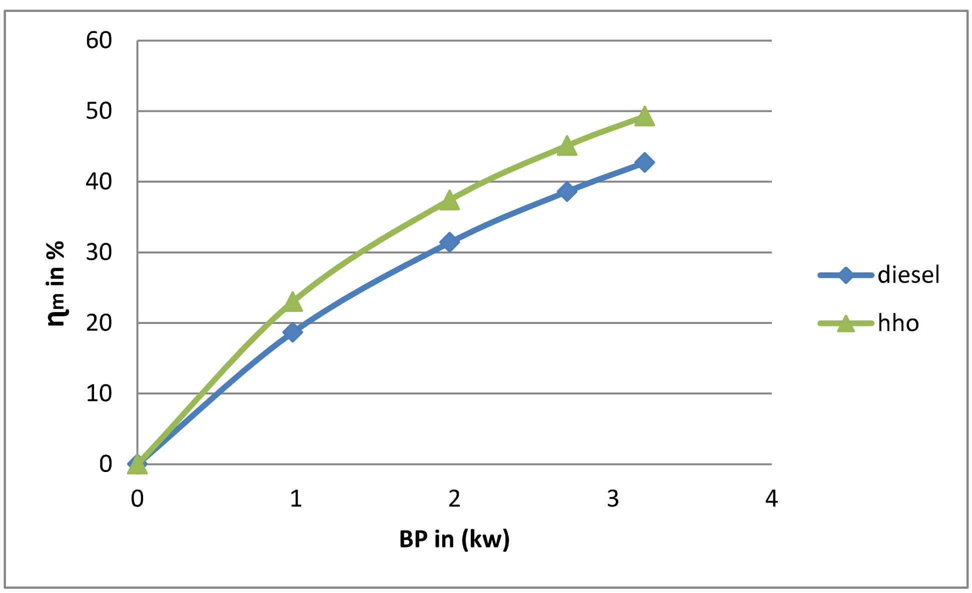

Figure 10.3 mechanical efficiency (η_m) v/s brake power (BP)

Chapter 11

COST DETAILS

SL NO	DISCRIPTION	QUANTITY	COST
1	ENGINE	1	14,500
2	Brake drum	1	1,000
3	Bearing with bed	2	1,800
4	Belt	1	100
5	Chain	1	400
6	Sprocket	2	200
7	Spring gauge	2	360
8	Electrodes(copper)	1	600
9	Case	1	200
10	Ball valve	2	400
11	insulators	1	200
12	Connecting wire(6sq.mm.-5mts)	1	200
13	AC to DC convertor	1	3,000
14	Labor Charges	1	3,000
15	Paint	1	300
16	Miscellaneous	1	2,000
		TOTAL	28,260.00

Chapter 12

ADVANTAGE AND DISADVANTAGE

12.1 Advantages of HHO gas as a fuel in Diesel engine

- HHO gas mixture burns nearly 10 times faster compared to gasoline air mixture.
- HHO ignition limits are much wider than gasoline's. So it can burn easily and give considerably higher efficiency.
- High self ignition temperature but very little energy is required to ignite it.
- Its clean exhaust is the most attractive feature of all.
- No green house effect.

12.2 Disadvantages of HHO gas as a fuel in Diesel engine

- Produces toxic emission of NO_x.
- One of the major practical difficulties using HHO as car fuel is its very low density either in gas or liquid form.
- The handling of HHO gas is more difficult and storage requires high capital and running cost.

Chapter 13

CONCLUSION

13.1 Optimum method of HHO generation

By comparing the reading from table 6.1 and table 6.2 the discharge of HHO gas is 14.4LPH for KOH and NaOH, which is almost same for both the cases. KOH solution produces lot of foams which leads to loss of concentration of electrolyte and in turn decrease the generation of HHO gas. Therefore comparing the production, rate of change of electrolyte concentration and cost of KOH and NaOH, NaOH electrolyte solution is best suited for the generation of HHO gas.

13.2 Performance characteristics of Diesel and HHO gas when used as a fuel

From graph 1up to 50% of full load, brake thermal efficiency will remain same for both the case. Beyond this point brake thermal efficiency increase linearly for fuel mixture of diesel and HHO gas. From graph 2up to 50% of full load for both cases the total fuel consumption increases linearly and reaches maximum value. TFC decreases more rapidly for fuel mixture of diesel and HHO gas than diesel as a fuel.

By comparing the results of above three graphs we can conclude that .The mixture of diesel and HHO gas gives better result for higher loads. Since HHO is highly combustible fuel, it ensures the complete combustion of the fuel mixture. Thus it results in the increased speed of the engine and in turn increases the power output.

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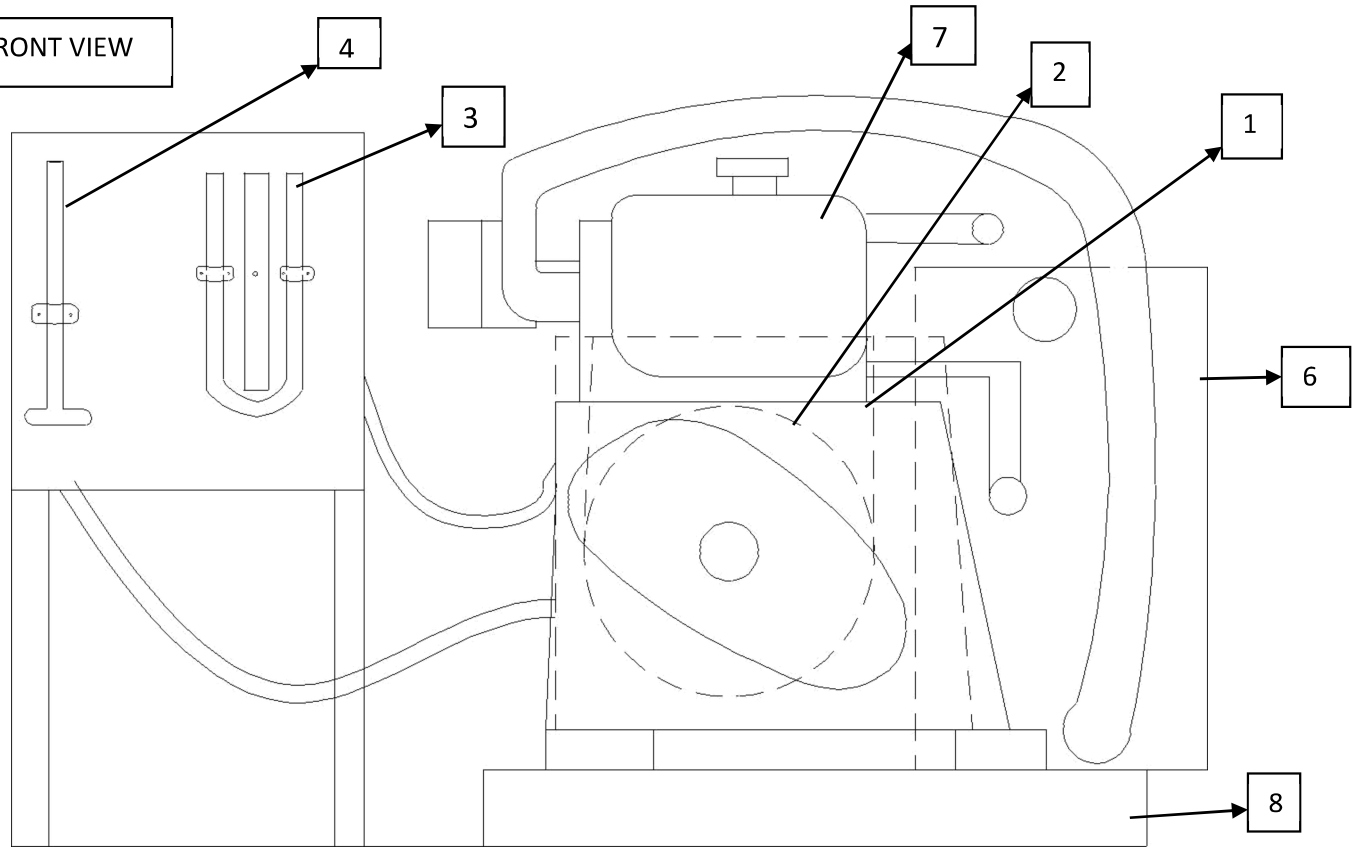
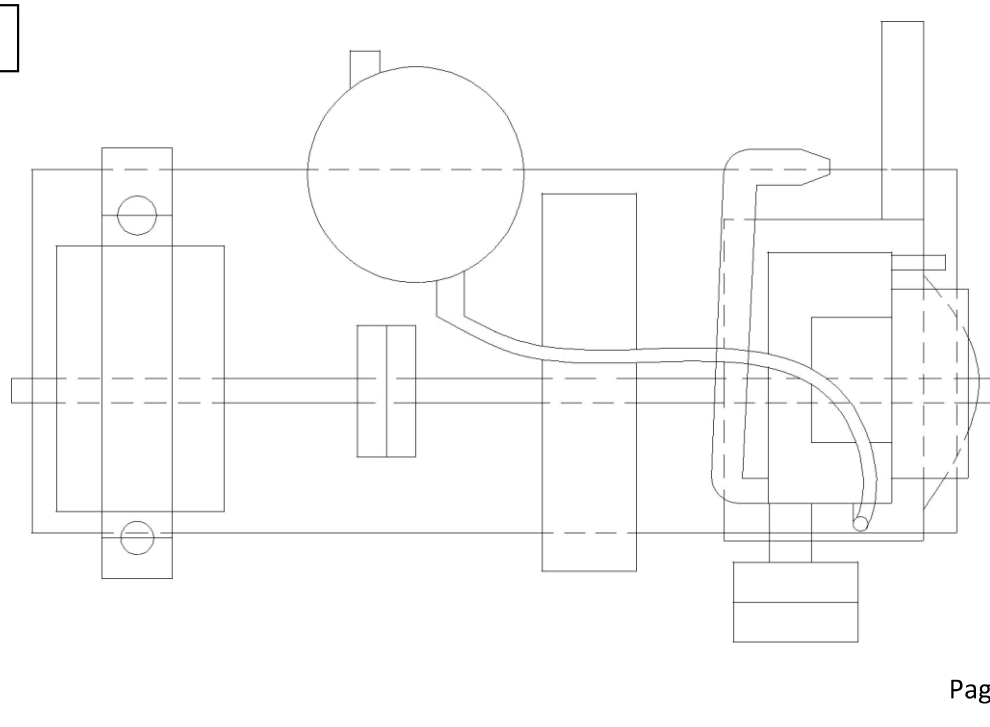
DRAWING

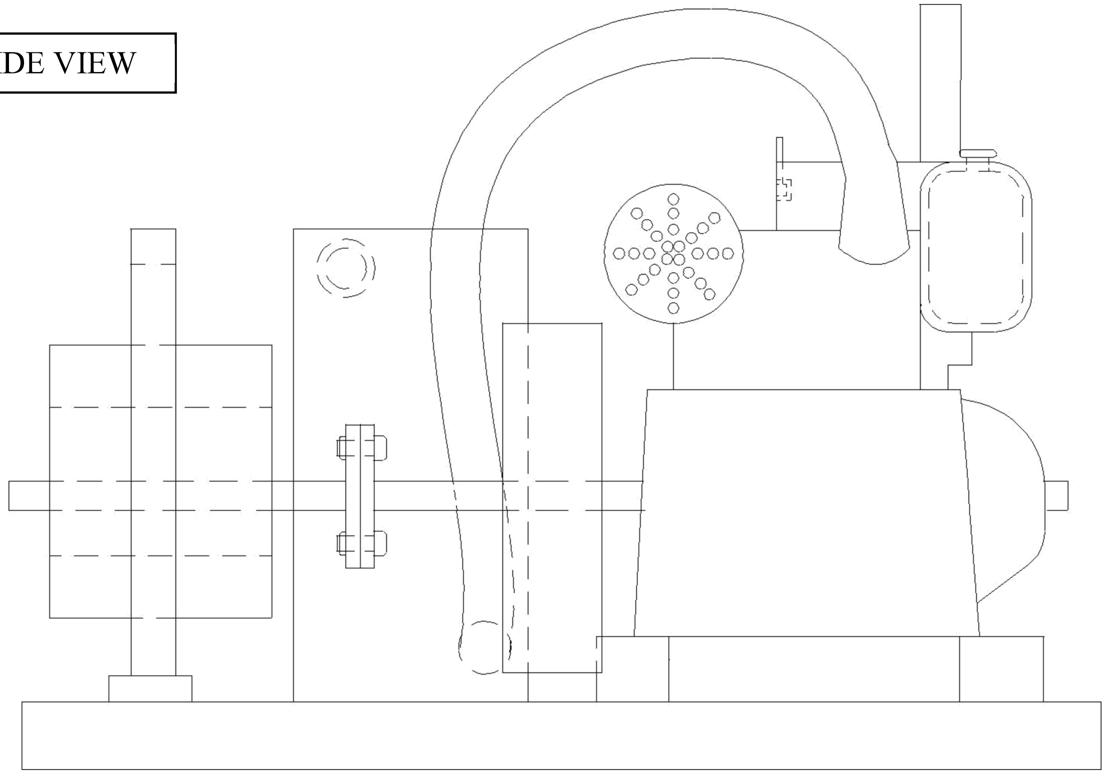
FRONT VIEW



TOP VIEW



SIDE VIEW



ALL DIMENSION IN METER

S.L NO	DESCRIPTION	MATERIAL	QUANTITY
1	ENGINE	CI	1
2	DYNAMOMETER	MS	1
3	MANOMETER	GLASS	1
4	BURETTE	GLASS	1
5	DIGITAL R.P.M METER	-	1
6	AIR DRUM	SM	1
7	FUEL TANK	AL	1
8	C-FRAME	STEEL	1

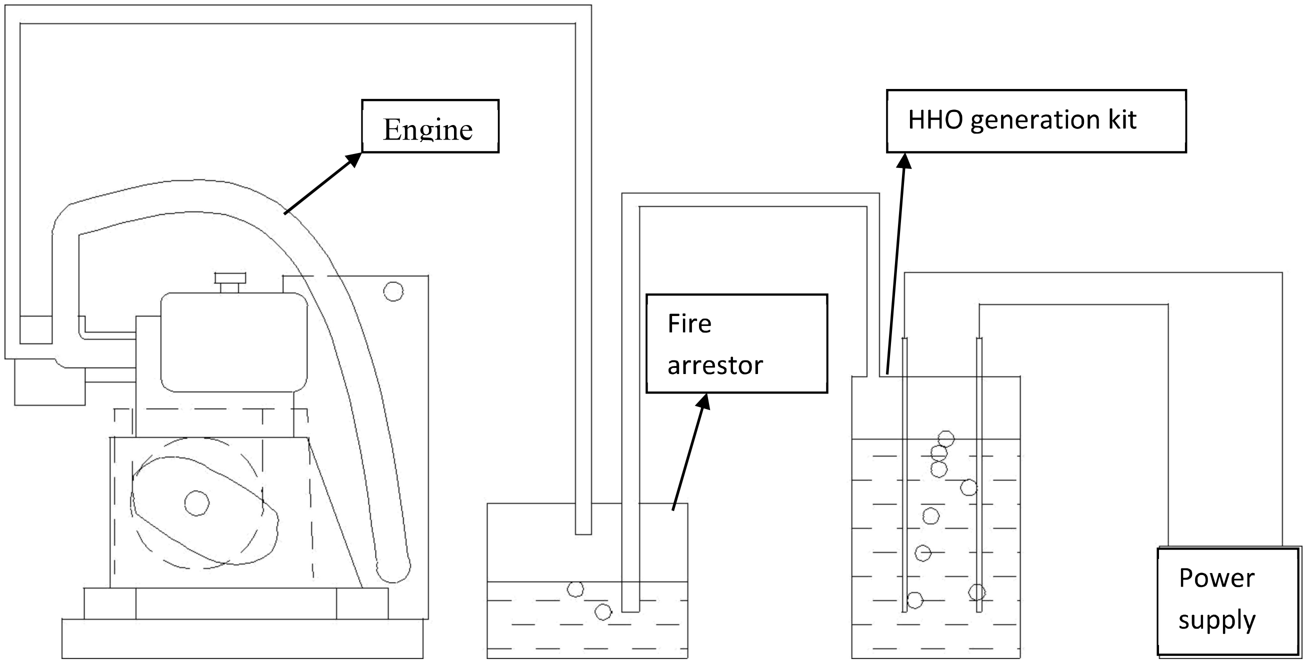


Figure A.1 Supply of HHO gas to Engine

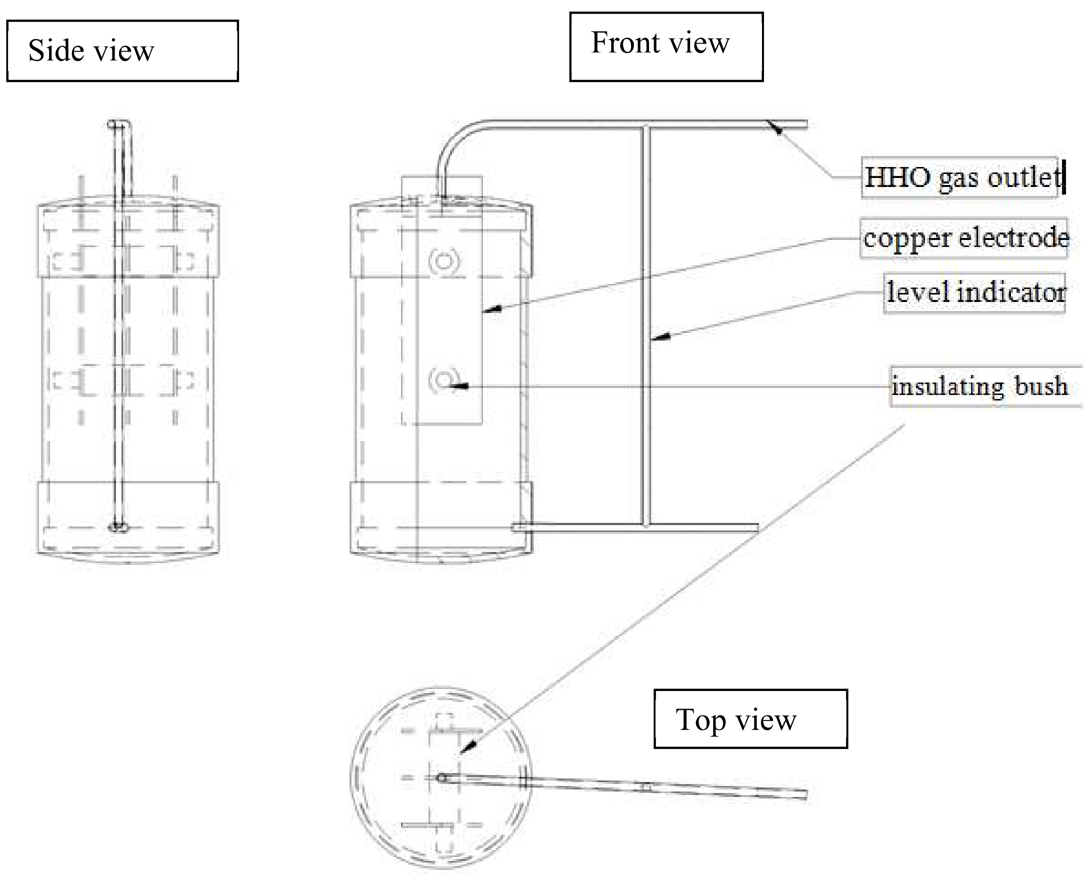
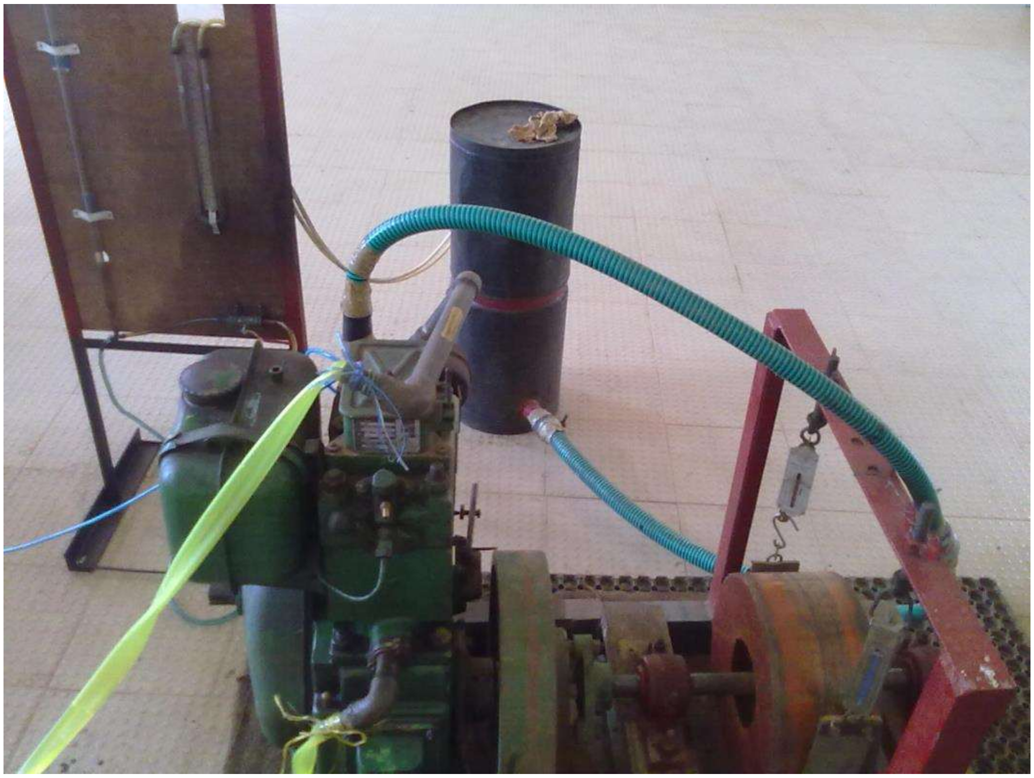
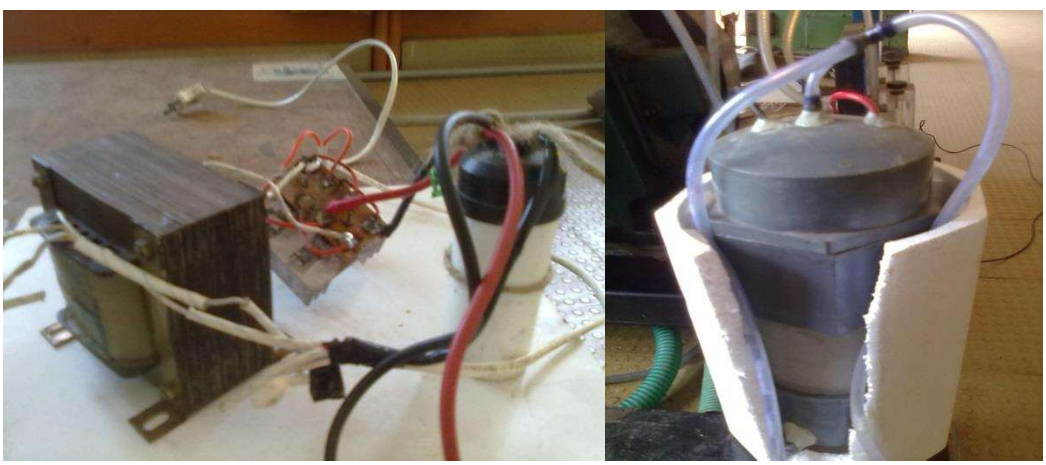


Figure A.2 HHO gas generation kit

PHOTOGRAPH



4-stroke single cylinder diesel engine test rig



HHO generation setup