ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
School of Mechanical, chemical and Material Engineering

Running Diesel Engine in dual Fuel mode with Diesel and HHO gas as fuels

A thesis submitted in partial fulfillment of the requirements for the Award of the degree of
Master of Science

in

Automotive Technology Teachers Education

By

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Adama

CANDIDATE'S DECLARATION

We hereby declare that this thesis entitled "Running Diesel Engine in dual fuel mode with Diesel and HHO gas as fuels'' in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive technology teachers education is an authentic record ofour own work carried out from March 2015 to May 30 under the supervision of N. RameshBabu (Associate Professor)Department of Mechanical and Vehicle Engineering, Adama Science and Technology University and MrAbinetGossayeDepartment of Mechanical and Vehicle Engineering, Adama Science and Technology UniversityEthiopia. The matter embodied in this thesis has not been submitted for the award of any other degree or diploma. All the relevant sources of information in this thesis have been duly acknowledged.

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This is to certify that the above statement made by the candidates is correct to the best of my knowledge and belief. This project report has been submitted for examination with my approval.

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Acronyms, Abbreviations and symbols

AC	Alternating Current
ASTU	Adama Science and Technology University
BG	Browns Gas
BSEC	Brake Specific Energy Consumption
BSFC	Brake Specific Fuel Consumption
BTDC	Before Top Dead Centre
CO	Carbon mono oxide
CRES	Corrosion-Resistant Steel
DC	Direct Current
DI	Direct injection
EGR	Exhaust Gas Recirculation
EPL	Electrolyte PerLitre
HC	Hydro carbon
FCEVs	Fuel Cell Electric vehicle's
HCCI	Homogeneous Charge Compression Ignition
HHO	Gas mixture made of 1/3 Oxygen and 2/3 Hydrogen by volume
HHV	Higher Heating Value
H_2O	Water
H2ICEs	Hydrogen fueled Internal Combustion Engines
HMI	Human-machine interface
HOD	HHO on demand
H_2-O_2	HHO
IC	Internal Combustion
K2CO3	Potassium Carbonate
KOH	Potassium Hydroxide
N	Negative
N_2	Nitrogen
NaOH	Sodium Hydroxide
NOx	Nitrate of oxides
Nu	Neutral
P	Positive
PLC	Programmable Logic Controller
PVT	Pressure volume temperature
RPM	Revolutions per minute
SMIs	Small and Medium Scale Industries
STP	Standard temperature and pressure
TVET	Technical and Vocational Education Training

ABSTRACT

In the present scenario the growing concern of the people living in every part of society is the ever increasing price of fuel and the harmful effects caused due to higher level of pollutants in the atmosphere. One of the closest solution to control the above two concern is the evolution of the hybrid vehicle. So our objective is to run diesel engine in dual fuel mode with diesel and HHO gas as fuels. The hybrid vehicle attempts to significantly increasing the mileage and reduce the emission levels of a gasoline powered engine and Diesel Engines. The water hybrid vehicle uses an HHO (Oxy Hydrogen) generator to supply hydrogen on demand by Electrolysis. The Electrolysis process is carried out in HHO Dry Cell, when the current starts flowing through the stainless steel plate's electrolysis process is carried out between the 2 terminals of the plate by which water molecules get separated as HHO gas. The water hybrid system is an attempt to provide an affordable low emission fuel efficient vehicle with performance standards better than most of the conventional Engines. As the speed increases both power and tractive force increases up to some point and then decrease. The power developed by the engine operated on HHO gas is more as compared with pure diesel. Tractive force increases, for engine operated with HHO gas is more as compared with pure diesel. Total fuel consumption of the engine, for engine operated with pure diesel is more as compared with engine operated with HHO gas, 21.3% of fuel is saved by using hydroxyl gas system. This is the safest method to reduce greenhouse effect in the future by installing this HHO generator in all two and four wheelers vehicles.

Key words: HHO Dry cell, HHO (Oxy Hydrogen), electrolysis, Emissions, KOH.

1. INTRODUCTION

1.1 Background of the study

Because of its energy efficiency and widespread fuel availability, Diesel technology serves as the primary power source used for surface transportation of bulk, freight and containerized cargo. Therefore, the surface network of the global logistics system is powered largely by diesel technology. It also powers the majority of industrial construction, agricultural and mining equipment.

HHO gas injection is a largely undeveloped technology that could very possibly be used to increase efficiency of diesel technology resulting in billions of dollars in reduced fuel costs.

In 1972, the Royal Navy examined how the Fleet should be fuelled when current fossil fuels become too scarce, say in the year 2030. They concluded that the fuel of the future was hydrogen but since the gas was not normally available in usable form, it would have to be extracted through either electrolysis of water or nuclear fusion or by dry cell. The effects of current known phenomena of HHO and water on diesel engine exhaust emissions and fuel consumption will be discussed. There has been much conjuncture in the public domain as to the effects on fuel economy of hydrogen on-demand systems made for internal combustion engines, as is evident with a simple search on the internet. The water hybrid vehicle uses an HHO (Oxy Hydrogen) generator to supply hydrogen on demand by Electrolysis. The Electrolysis process is carried out in HHO Dry Cell, when the current starts flowing through the stainless steel plates electrolysis process is carried out between the 2 terminals of the plate by which water molecules get separated as HHO gas. The integration of this produces great results. The IC Engine of hybrid vehicle during operations simultaneously charges the battery using alternator which run through generator. The water hybrid system is an attempt to provide an affordable low emission fuel efficient vehicle with performance standards better than most of the conventional Engines.

1.2. Statement of the problem

In the present scenario the growing concern of the people living in every part of society is the ever increasing price of fuel and the harmful effects caused due to higher level of pollutants in the atmosphere. One of the closest solution to control the above two concern is the evolution of the hybrid vehicle. Any vehicle that combines one or more sources of on board power that can directly or indirectly provide propulsion power is a hybrid vehicle. The hybrid vehicle attempts to significantly increasing the mileage and reduce the emission levels of a gasoline powered engine and diesel Engines. This project Build and install a low-cost alternative method for running our vehicle on tap water, using HHO Dry Cell. This is simply an efficient way to convert ordinary tap water into gaseous hydrogen and oxygen, and then burn these vapors in the engine, instead of diesel.

1.3 Significance of the study

Most of the Car manufactures around the world are developing hydrogen-fueled vehicles. Mostly fuel cell electric vehicles (FCEVs) but some company such as BMW, Honda and Mazda are developing cars powered by hydrogen fueled internal combustion engines (H2ICEs). Mainly due to the high demand of fuel and its main associated problems for the environment such as air pollution and gas emissions.

- Dual-fuel internal combustion engine vehicles that combine diesel and hydrogen could be the alternative solution for speeding up the introduction of hydrogen in the vehicles.

- The water-hybrid system is called a conversion system because it doesn't require removal, modification, or disabling of any of our vehicles' existing systems. Therefore, it allows us to run our vehicle on either 100% diesel systems or the water-hybrid system. In the unlikely event that our water-hybrid fails, you can easily switch back to solely using diesel power.

- It is significant to note that the small micro enterprises, industry and particularly the garages and TVET institutions will benefit in knowing the great investment opportunities in using the developing and modifying the systems.

- The findings will help the government in coming up with strategies that will reduce fuel importing from foreign countries, this will have positive impact on the country's economy.

- The maintenance becomes very simple. It is realized to check the protection fuse every week (we should check it frequently in the first week after installation) and check the water level inside the water tank, monthly we should clean the transfer unit and remove all deposits.

1.4 Objectives

1.4.1. General objective

The general objective of this project is to Run Diesel Engine in dual Fuel mode with Diesel and HHO gas as fuels.

1.4.2. Specific objectives

- To design HHO dry cell
- To construct HHO dry cell
- To modify the fuel system of diesel engine for handling HHO gas
- To run diesel engine with HHO gas and diesel fuel

1.5. Scope of the project

Since hydrogen planet cells has many applications like home generator system, heating, turbine and can run any type of engine on hydrogen and oxygen gas, which would include , Truck, lawn mower, gas powered weed eater, airplane engines, etc..This project is limited to running diesel engine in dual fuel mode with diesel fuel and HHO gas (by splitting water into flammable gases, Hydrogen and Oxygen by electrolysis).

1.6. Limitations of the project

- Performing sufficient experimental testing is difficult because of unavailability of testing equipment
- Since most of the vehicle use liquid fuel there is a shortage of gaseous fuel measuring device
- Performing all the necessary measurement and testing is difficult because of the shortage of time

2. LITERATURE REVIEW

2.1. Properties of Brown's Gas

BROWN'S GAS is created via the process of water electrolysis where the hydrogen and oxygen are allowed to stay mixed. Water contains a ratio of 2 parts hydrogen to one part oxygen bonded in a tetrahedral molecular arrangement with two lone pairs of electrons and two bonding pairs of electrons connecting the hydrogen atoms to the central oxygen atom. Eckman (2010) [4] proposed that when water is electrolyzed and the gas products are not separated by a semi-permeable membrane, Rydberg clusters may be formed. These clusters are of a mixture of hydrogen and oxygen species including linear water molecules in the highly energized trigonal-bypyramidal geometry, monatomic and diatomic hydrogen, free electrons and oxygen as shown in figure 2.1.

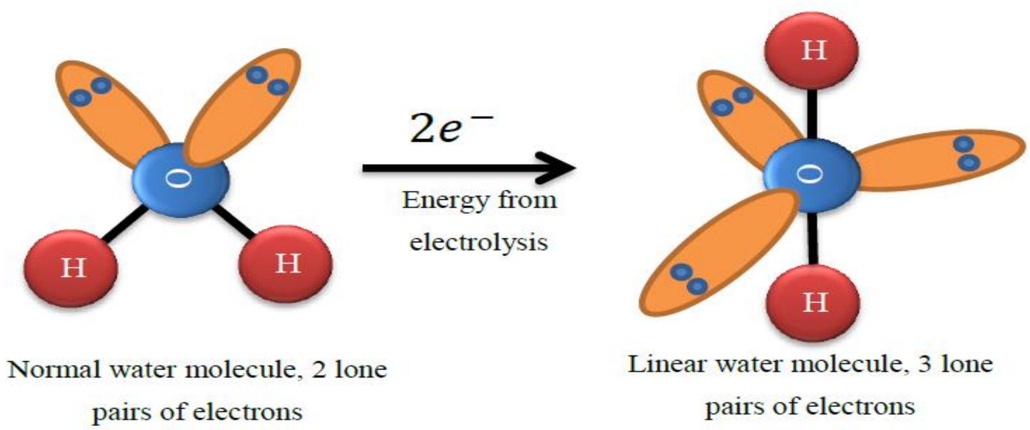


Figure 2.1: Rydberg clusters containing water molecules with highly energized electrons, but unenergizednucleiEckman (2010).

The extra energy stored in one litre of HHO due to Rydberg clusters is theorized to be 600±34J. Rydberg clusters are most common in solids and liquids and are typically stable from nanoseconds to hours. In the case of HHO or Brown's Gas these clusters have shown a life span of 11 minutes Eckman (2010) [4]. Due to these highly energized clusters HHO contains much more energy than equivalent stoichiometric ratio of hydrogen and oxygen in the form of extra electrons, this state has been explained as cold plasma. Cold plasma is a state of matter where the atom nuclei are relatively unenergetic or slowly moving, but the electrons are in highly energized states at higher atomic orbitals. If this is true HHO releases additional electrons during combustion that are stored in the gas resulting in higher electrical and thermal energy transfer compared to the equivalent mixture of hydrogen oxygen and water. Normally the presence of water in a burning fuel gas greatly reduces the heat energy due to the high specific heat capacity of water (4.18J/g K), however the linear water content of HHO has greatly reduced hydrogen bonds and electrically transfers its electrons under combustion at the surface of the contacting material. The flame temperature generated by HHO can range from 150°C to over 9000°CR. M. Santilli(2006) [10] based on the contact materials' electrical conductivity, thermal conductivity, density and vapour point. The HHO generated for addition into the diesel engine in this research project will not have a water vapour removal (desiccant) stage at the output, so as to test the effects of the claimed additional energy release during combustion.

2.2. Hydrogen Assisted Combustion

This review covers tank hydrogen-diesel experiments that have several similarities to the experimental setup in this research project. Conditions for commonality include naturally aspirated diesel engine, constant engine speeds at or near 1500r/min replicating a generator, small rates of either hydrogen or HHO injection into the air intake, with fuel consumption and NOx emissions analysis. Throughout this paper, all gas mass flow rates are converted to volumetric flow rate at standard temperature and pressure – 298.15K and 101.325kPa. HHO injection is most commonly cited in terms of volumetric flow rates, so all references to hydrogen or HHO injection will be on a litre per minute injection base unit. Three values will be taken from. Firstly it takes 7.79kJ to produce 1L of HHO, and secondly the net efficiency of converting the equivalent diesel energy to HHO energy was between 11.4% and 16%. Thirdly 4.4Wh of electrical energy was required make 1L of HHO with the experimental setup; this includes losses from the switch mode power supply. Taking an arbitrary net HHO conversion efficiency of 15%, it would require 51.9kJ or 14.426W h of diesel energy to produce 1L of HHO.

Adnan et al. (2009)[9] found gaseous hydrogen injection rate of 20L/min at standard temperature and pressure (STP) doubled oxides of nitrogen (NOx) emission at 1500r/min in a 7.4kW 406cm3 naturally aspirated diesel engine, with a compression ratio of 19.3:1. The engine load or power output was not stated. The cylinder peak pressure increased 11% and delayed the peak pressure event 10° in the combustion stroke; indicated power increased 33% at 1500r/min. The power gain would correspond to a reduction of fuel consumption all things being equal. If the hydrogen was produced on-demand at 4.4Wh/L then the added load would be 5.3kW, leaving around 29% of the engines power for useful work, and most likely dramatically increasing diesel consumption.

Bose and Maji (2009)[8] injected 27.8L/min of hydrogen and EGR gas into a 5.2kW, 17.5:1 compression diesel engine running at 1500r/min under various loads. Break Specific Energy Consumption (BSEC) was reduced 64% and 36%,NOx emissions increased 70% and 90% at 20% and 40% load respectively due to hydrogen injection. The efficiency of the diesel engine increased due to the increased lean limit and flame speed due to the properties of hydrogen combustion. 27.8L/min of hydrogen is a high injection rate for a small engine if the hydrogen had to be split from water by the engines own power. If this hydrogen were to be produced on demand at 4.4Wh/L, the added load due to electrolysis would be 7.34kW – 41% greater than the engines rated power.

Miyamoto et al. (2011) [12] injected tank hydrogen at varying rates into a 551cm3 single cylinder diesel engine with a 16.7:1 compression ratio operating at a constant 1500rev/min. The engine had varying diesel injection timing, and the coolant and air temperature were maintained at a constant level. Diesel injection timing was from 12° to 0° BTDC; NOx emissions due to 6.0% vol. H2 injection caused NOx to drop 24% at 12° BTDC injection timing, to equal the NOx emissions with no hydrogen injection.

Lilik (2010) [6] tested the effects of small ratios of hydrogen injection on a 2.5L turbo diesel engine operating at 1800r/min, 25% and 75% rated engine load. Some of the key results are shown in Table 2.1 Overall NOx emissions and brake specific fuelconsumption increased with tank hydrogen injection H_2 has a negative impact on BSFC. The hydrogen injection in the turbo diesel engine had the opposite effect on diesel consumption.

Table 2.1: Change in NOx emissions and BSFC on a 2.5L turbo diesel at 1800r/min

parameter	2.5% FE H_2 25% Load	2.5% FE H_2 75% Load	5% FE H_2 25% Load	5% FE H_2 75% Load
NO	-16.9%	-3.4%	-24.2%	-5.4%
NO_2	+53.3%	+72.1%	+68%	+87.1%
BSFC	+0.3%	+0.4%	+0.6%	+0.6%

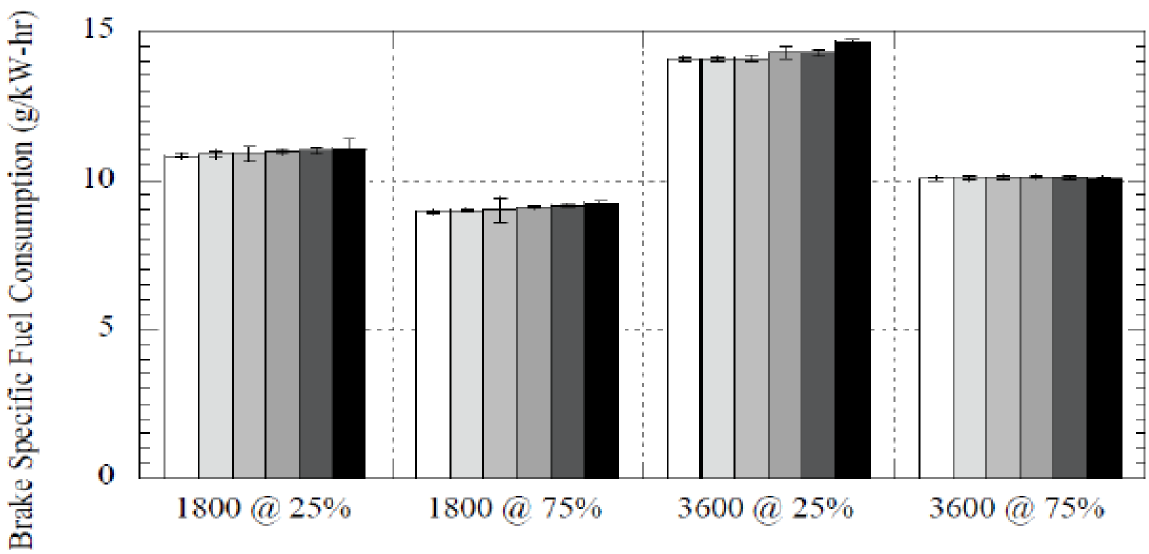


Figure 2.2: Brake specific fuel consumption for a 2.5L turbo diesel engine, courtesy Lilik (2010) [6].

The above figure shows brake specific fuel consumption for a 2.5L turbo diesel engine, courtesy Lilik (2010) [6].

With all the literature reviewed so far, NOx increases with load and hydrogen injection rate. The increase in fuel economy due to hydrogen injection is not sufficient to offset the energy required to make the equivalent volume of hydrogen by electrolysis of water using the engines power. A small rate of water injection could be a means to offset in cylinder temperature rises created from hydrogen and therefore reduce NOx emissions, without significantly reducing the reduction of fuel energy made available from electrolysis. Based on hydrogen experimental research, on-board HHO would appear to increase diesel consumption, and proportionally decrease the available usable engine power.

2.3. HHO as an additive in diesel engines

Bari and Esmaeil (2010)[11] operated a 4L direct injection (DI) diesel engine in simulated generator mode at three loads at constant speed, supplying 0-32L/min of HHO supplied by an externally supplied high power waterelectrolyser. Yilmaz et al. (2010) [2] injected small rates of HHO into a diesel engine and performed tests with engine load, speed and two stage unspecified HHO delivery rates as the system input variables. Experiments performed by both teams of researchers showed positive results in improving the fuel efficiency of the engines, but the quality of the data and equipment varied significantly. They also operated a 4L DI diesel engine generator at three loads at 1500r/min, supplying up to 32L/min of HHO supplied by an externally powered electrolyser. They sought to verify whether an on-board electrolyser can reduce fuel consumption in a diesel engine. They reported around 14-15% reduction in fuel energy consumption (diesel and hydrogen energy both included) across all loading conditions and HHO injection rates. They found HHO is best used in small ratios, up to 4% because up to this injection rate HHO acted as an additive rather than a 1:1 diesel replacement fuel. NOx emissions increased up to 27% with an increasing rate of HHO injection, the same as for tank hydrogen injection. There were a couple of problems with the experimental setup, the first was in the use of a Dwyer air flow meter, and the second was in the assumption of unattainably high oxy hydrogen efficiency. The author attempted to use the same brand of flow meter to measure HHO production, but found the Dwyer flow meter indicated 4.5L/min of gas when in fact 6L/min was measured using an upside down bucket test due to the lighter density of hydrogen in the HHO mixture. If there is this much constant measurement error, then the HHO gas rates would be 33% higher than stated in the paper, significantly over optimizing the BSFC results. The water electrolyser used in the experiment was an Epoch model EP-500 water electrolyser, rated for an input power of 11.5kW, consuming 1.4L/h of water the equivalent of 47.53L/min of HHO at 4Wh/L (using the PV=nRT gas volume formula), this would confirm the 33% underestimate of HHO addition.

Table 2.2 below takes Bari and Esmaeil's HHO volume and energy claims and modifies them to reflect the previously stated assumptions for the power requirements of a realistic water electrolysis system (4Wh/L) and the volumetric flow rate discrepancy due to using an air flow meter. Running such a high rate of HHO would reduce the available power to supply useful electrical loads – and potentially reduce fuel economy if the HHO gas did not have a strong additive effect.

Table 2.2: Added electrical load due to on-board water electrolysis

Dynamometer load	HHO (claimed**)**	HHO (adjusted)	Electrolyser Power	% electrolyser Load/dyno load
19kW	31.7L/min	42.3L/min	10.14kW	53.37%
22kW	29.8L/min	39.7L/min	9.54kW	43.3%
28kW	30.6L/min	40.8L/min	9.79kW	35.0%

Yilmaz et al. (2010)[2] reduced diesel consumption an average of 14% across the range of speeds tested, with the highest gains in economy at the higher engine speeds. This could be due the HHO mixture speeding the combustion, leading to a more efficient pressure profile. There are several omissions and major concerns with the Yilmaz et al research paper. Firstly the volume of HHO injected and the efficiency of the HHO system was not mentioned, only the power used to run the electrolyser. The HHO was not injected at a constant ratio to diesel, unlike the Bari and Esmaeil experiment, rather in two rate profiles – 43W of HHO below 1750r/min and 120W above 1750rev/min. Thedata plotted as one series as can be seen below in Figure 2.3.

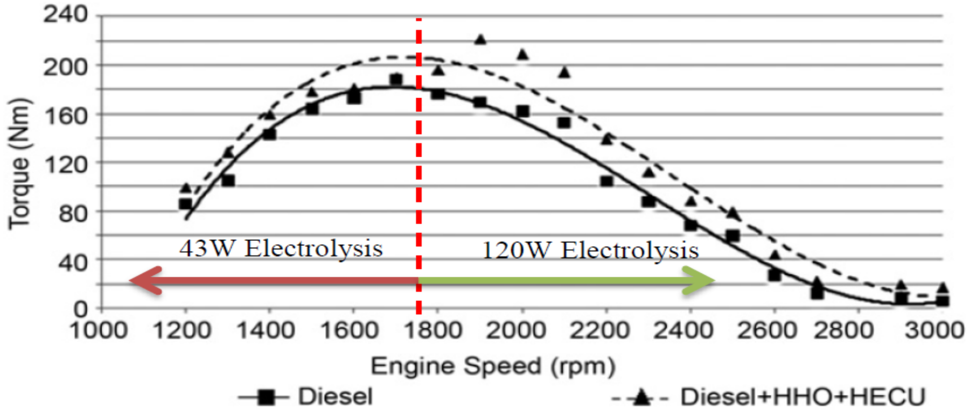


Figure 2.3: Variation of engine torque with speed, and two rates of HHO fromYilmazetal.experiment (2010) [2].

Another concern was with the BSFC of the test engine. Under both stock conditions and HHO test conditions, specific fuel consumption was inordinately high; ~1100g/kWh at 1800r/min to ~1750g/kWh at 3000r/min – compared to a range of 232-262g/kWh for a similar sized engine operated by Bari and Esmaeil, leading to doubt in the integrity of their data measurement system.

2.4.Combustion of Hydrogen with Diesel

M. Mikami, (2011) [12]investigated the engine performance and emissions of a super charged four strokes, single cylinder, and water cooled diesel engine fueledwith hydrogen and ignited by a pilot amount of diesel fuel in dual-fuel mode. Theengine was tested for use as a cogeneration engine. The experiments were carriedout at a constant pilot injection pressure of 80 MPa and pilot quantity of 3mg/cycle for different fuel-air equivalence ratios and at various injection timingswithout and with charge dilution. The intake pressure of air was kept constant at200 kPa and the temperature was maintained at 30^{o}C throughout the study. Theirexperimental strategy was to optimize the injection timing to maximize the enginepower at different fuel-air equivalence ratios without knocking and within thelimit of the maximum cylinder pressure. They first tested the engine withhydrogen-operation condition up to the maximum possible fuel-air equivalenceratio of 0.3. A maximum IMEP of 908 kPa and a thermal efficiency of about 42%were obtained. They observed that the equivalence ratio could not be furtherincreased due to knocking of the engine. The emission of CO was only about 5ppm, and that of HC was about15 ppm. However, the NO_x emissions were high100 to 200 ppm. Then they performed charge dilution by N_2 to obtain lower NO_xemissions. They achieved 100% reduction in NO_x. According to them, this was due to the dilution by N_2 gas which paved the way for injection of higher amountof hydrogen without knocking. Because of this charge dilution, they got 13%higher IMEP than IMEP produced without charge dilution. At an equivalence ratio of 0.20, the maximum cylinder pressure increased gradually with advancing injection timings. The maximum cylinder pressure was 9.27 MPa at an injectiontiming of 10^o BTDC, and reached its highest level of about 12 MPaat 18^oBTDC.The maximum cylinder pressure at an injection timing of 5^o BTDC and anequivalence ratio of 0.25 was 8.6 MPa, and reached its highest level of 12.6 MPaat 13^o BTDC. The maximum cylinder pressure at an injection timing of 4^oBTDCand an equivalence ratio of 0.30 was 8.75 MPa, and reached its highest level ofabout 10 MPa at 6.5^o BTDC. The maximum cylinder pressure was very low at anequivalence ratio of 0.30 because in that case the injection timing needed to beretarded to avoid knocking. At a constant equivalence ratio, the NO_xemissionincreased with advanced injection timings. Advancing the injection timingincreased the peak cylinder pressure, and higher peak cylinder pressures resultedin higher peak burned gas temperatures, and hence more NO_x emission. MoreNO_x was produced as the equivalence ratio got increased, although the injectiontimings were retarded. The highest NO_x emission level was about 200 ppm at anequivalence ratio of 0.25 to 0.30. HC emitted by the dual-fuel engine fueled byhydrogen varied from only 14 to 18 ppm. The CO emitted by the dual-fuel enginefueled by hydrogen varied from only 5 to 7 ppm. The level of NO_x of 200 ppmwith hydrogen-operation was reduced to 0 ppm level with 60% N_2 dilution. Therewas about 98% and 99% reduction in NO_x for 40% and 50% N_2dilution,respectively. However, HC increased to the level of about 80 ppm with 60% N_2dilution. CO increased to the levels of about 80 ppm and 500 ppm with 50% and60% N_2 dilution, respectively. They concluded that by diluting the charge with N_2,the hydrogen engine could be operated without engine knock.Lilik et al (2010) [6] reported about the hydrogen assisted dieselcombustion on a DDC/VM Motor 2.5L, 4-cylinder, turbo-charged, common rail,direct injection light-duty diesel engine. Their main focus was on the study ofexhaust emissions of the engine. They substituted hydrogen for diesel fuel on an energy basis of 0%, 2.5%, 5%, 7.5%, 10% and 15% by aspirating hydrogen into the engine's intake air.

This resulted in significant reduction in NO_x emission. They alsoobserved that the same emission reductions were possible without aspiratinghydrogen by manually retarding the injection timing. To study the hydrogenassisted diesel combustion, they locked the injection timings of the pilot and themain fuel.

Shah, (2010) [14] found a way to reduce the concentration ofpollutants coming out from a diesel engine. They blended hydrogen gas withhydrocarbon fuels used in internal combustion engines. They carried out theirexperimental research in a four stroke air cooled diesel engine. Their hydrogenfueling system consisted of a hydrogen bottle, two pressure reduction valves toreduce the hydrogen pressure to 2 bars, a hydrogen flow meter and an injector.The injector was mounted on the inlet pipe at 10 cm from the engine with an angleof 45^o with the direction of injection. The hydrogen injection timing wascontrolled by an electronic control unit designed for this purpose. They chosethree different speeds of 1000 rpm, 1250 rpm, and 1500 rpm. They also varied theload from no load to 80% of full load and the hydrogen blending ratio was variedfrom zero (pure diesel) to 10% (by mass) of the injected diesel fuel. Their resultsshowed that 10% hydrogen blending reduced smoke opacity by about 65%.Itincreased the nitrogen oxides concentration by about 21.8% and reduced CO_2andCO concentrations by about 27% and 32% respectively. This trend was found atall tested speeds and loads. They observed that the concentration of NO_x generally increased with hydrogen blending ratio for all loads. They related this to theimprovement of combustion process caused by the presence of hydrogen in thefuel mixture which led to higher cylinder temperature. They also stated that theNO_x formation reactions were highly temperature dependent.

2.5. Hydrogen Generators-making out of Water

According to Bari and Esmaeil (2010)[11] the technology has been around for over a century, progress has been slow to develop an Alternative fuel from this planet's most abundant commodity known as water. With the increased dependence on fossil fuels from oil, the costs of this vital resource are escalating along with damage caused by air pollution. Global warming is a very important and real threat issue that can reduce our chances for survival in the future.

Water may just save us, if we use it wisely and keep it from becoming polluted also. The most abundant element in the known universe is hydrogen. Water is composed of two atoms of hydrogen (H) and one atom of oxygen (O).Thus H2O= Water. There is a device called a Hydrogen generator that uses a process known as electrolysis to separate and extract both hydrogen and oxygen out of water. Earlier developments for hydrogen generators were designed to extract HHO or sometimes referred to as Browns Gas.

2.6. 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 favorable 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.

Shah, (2010) [14] found 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 releasing 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, GermanKnall-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.

2.6.1. Propertiesof 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 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 molecularbond 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 electrolysis.

3. MATERIALS AND METHODS

3.1. Material used to construct the project

According to Yilmaz et al. (2010), there are different materials and components which are used to construct HHO dry cell. These systems and components are well constructed to produce the final project result.

In metallurgy, stainless steel, also known as inox steel or inox from French "inoxydable", is defined as a steel alloy with a minimum of 10.5 or 11% chromium content by mass. Stainless steel does not corrode, rust or stain with water as ordinary steel does, but despite the name it is not fully stain proof. It is also called corrosion resistant steel or CRES when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment the alloy must endure. Stainless steel is used where both the properties of steel and resistance to corrosion are required. Since stainless steel resists corrosion, maintains its strength at high temperatures, and is easily maintained, it is widely used in items such as automotive and food processing products, as well as medical and health equipment. The most common US grades of stainless steel are: Type 316, the most commonly specified austenitic (chromiumnickel stainless class) stainless steel, accounting for more than half of the stainless steel produced in the world. This grade withstands ordinary corrosion in architecture, is durable in typical food processing environments, and resists most chemicals. Type 316 is available in virtually all product forms and finishes.

Stainless steels are available in the formof plate, sheet, strip, foil, bar, wire, pipes and tubes.There aremany advantages and benefits to using an acrylic sheet over something like plastic or glass.Rubber rings are used toseparate the stainless steel plates and prevent the distilled waterfrom being drowned between the plates.The stainless steel boltsand nuts are used to prevent the corrosion caused due to theiraction in between the stainless steel plates and distilled water. These nuts and bolts are corrosion resistant and prevent anyfurther reaction.

Table 3.1: material used to build HHO gas dry cell

Material	Specification (mm)	Quantity
Stainless steel plates	160 X 200	3
Stainless steel plates	160 X 180	8
Plexiglas	180 X 220	2
Plastic gasket	160 X 180	12
Bolt	Ø8.5	12
Washer	1mm thick	12

Figure 3.1 materials used to build HHO gas dry cell

The above table and figure shows material used to build HHO gas dry cell.

3.1.1. Electrodes

There are different materials could be used as an electrode. But each one has its own merits and demerits.From the overall search the selection of material for electrodes should be stainless steel thicker in size. The electrodes shape is either in plate or tube form. The number of electrodes depends on our gas requirements. The distance between each plate should be minimum and should have equal space all over the arrangement of electrodes. There are two methods of arrangements of electrodes; without-neutral and with-neutral. The without-neutral electrodes construction consists of number of positives P and negatives N plates which are all arranged alternatively, example if there are three set of positive and negative electrodes then P-N-P-N-P-N is the arrangement. Next with-neutral electrodes construction consists of number of positives P,neutralNu,and negatives N plates which are all arranged in the following manner N-Nu-Nu-Nu-Nu-P-Nu-Nu-Nu-Nu-N.

We design the three plates: power plates, neutral plates and end plates as shown below.

A. Power plate

The figure below shows the three powerplates are about 0.8mm thick (160mm x 200mm) stainless steel. A 10mm gas vent hole is drilled in each plate. Staggering and using small holes minimizes any efficiency loss due to current leakage between cells, but makes electrolyte refilling and level equalization significantly easier.

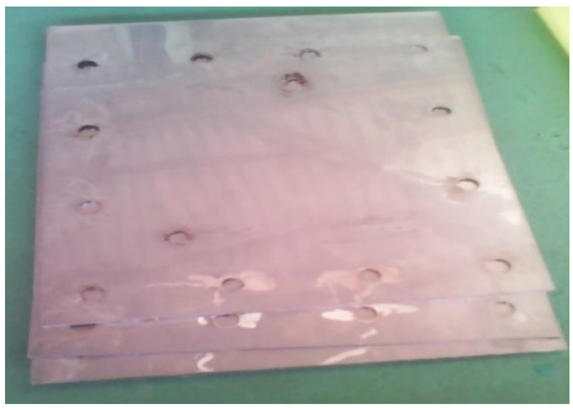


Figure 3.2: (a) Power plate

B. Neutral plate

The figure below shows the neutral plates are also about 0.8mm thick (16mm x 18mm) stainless steel.Fourteen 10mm holes were drilled for size steel alloy throughbolts. Two holes are used to circulate electrolyte.

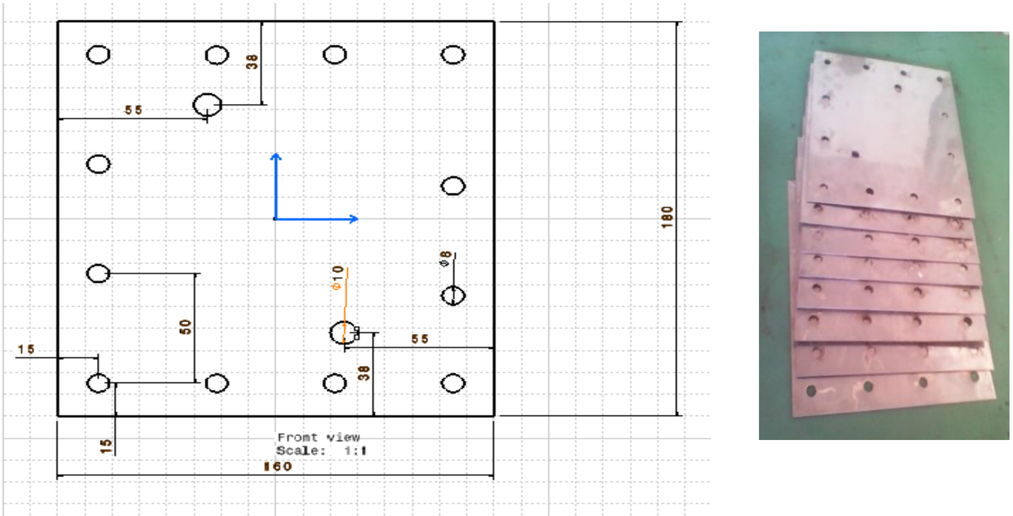


Figure 3.2: (b) Neutral plate

C. End plates (plastic covers)

The figure below shows the sizes of the end plates are (210mm x 180mm). Fourteen 10mm holes were drilled for size steel alloy throughbolts. From fourteen holes two are used for inlet and outlet port.

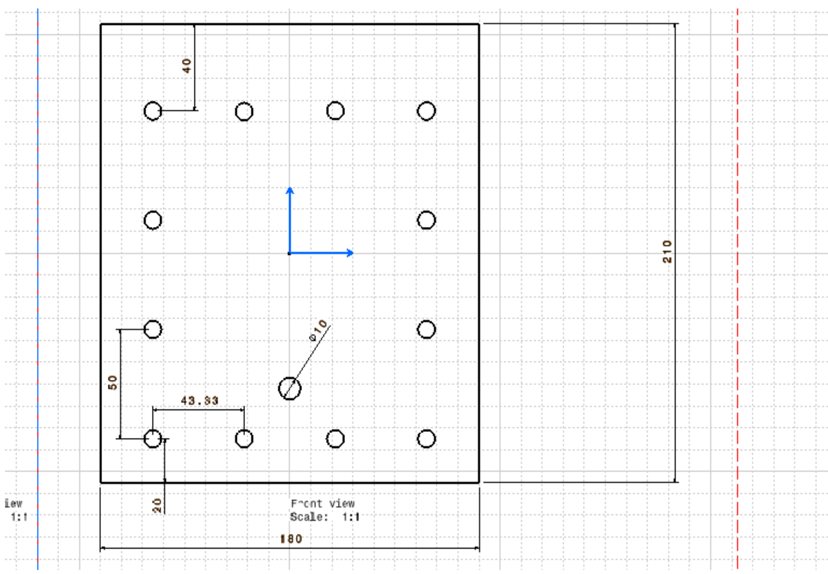


Figure 3.2: (C) Outer covers(end plates)

D. Plate separator (plastic gasket)

There is a plastic gasket (spacer) between each plate. Plastic gasket (160mm x 180mm) 12 pieces used to isolate each plate. 12 holes were drilled as shown in the figure below.

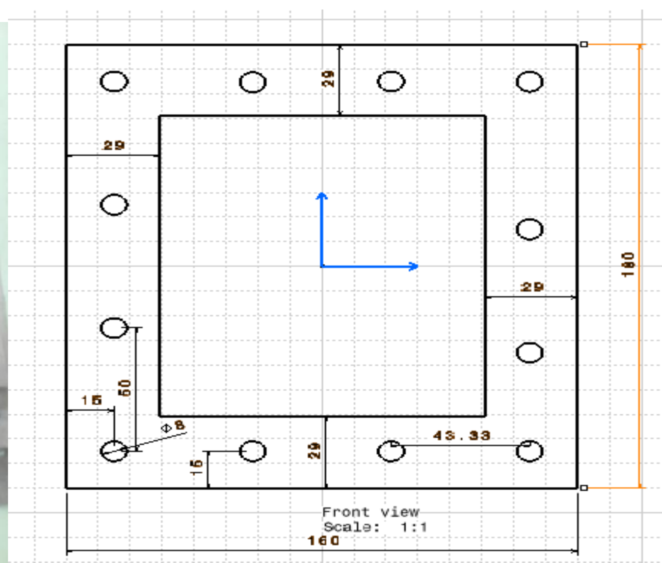


Figure3.2: (D) Plastic gasket (plate separator)

3.1.2. Assembled Gas Generator

The finished electrolyzer is shown in Figure 3.3. The two end plastic plates are clamped together with 70mm long stainless steel bolts with Nylon nuts. This softened the gaskets and allowed the stack to be tightened up even further to provide an excellent seal.

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 oxy hydrogen gas or HHO gas. The HHO gas has the same combustible property as that of Hydrogen.

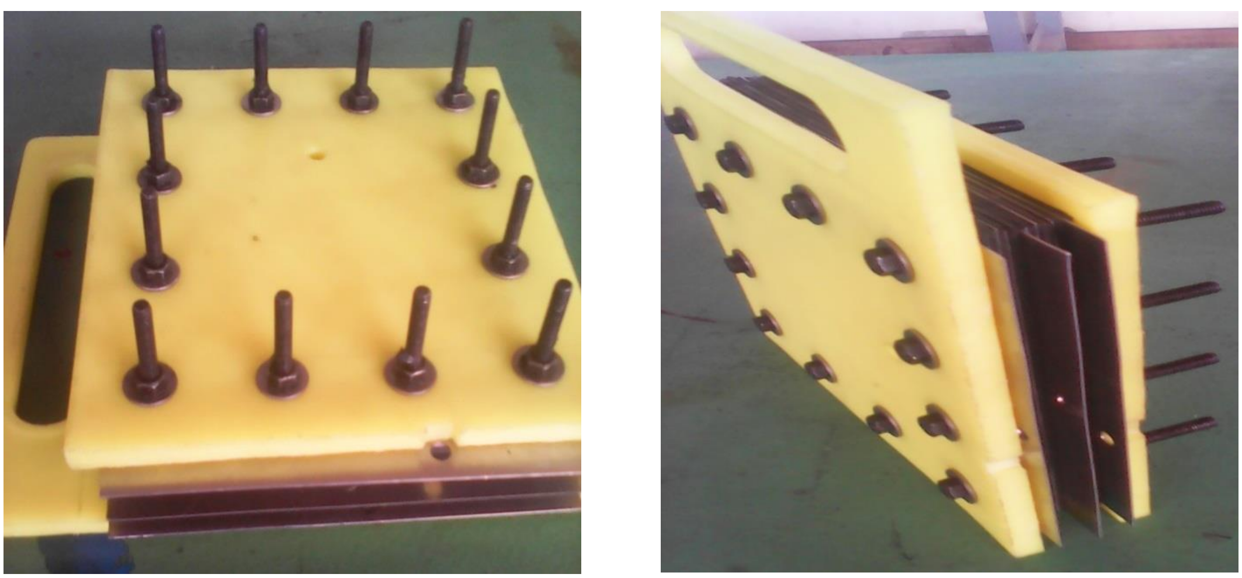


Figure 3.3: assembled gas generator

3.1.3. Water Container and Bubbler

Bubbler is otherwise called safety bubbler or collector, which has a simple arrangement. The container should be flexible and withstand the vibration and little bit pressure, transparent and should have feet of height. These all conditions are satisfied by a simple water bottle made of plastic. With the incoming and outgoing plumbing works are as shown in figure 3.4 below, then it is called Bubbler. The three fourth of the bubbler should filled with water.

The gas incoming tube from the gas generatorshouldbe dipped into bottom of the water level always. For that purpose the side of the tube is pasted up to bottom level of the bottle with little gap to let gas bubbles from the tube to the top of the water level. The outgoing tube should be at the top of the bottle top. This bubbler solves two important problems as thegeneratedgas generatorbubbles are washed and avoid the chemicals from electrolyze to flow into engine and another important function is protection of flashback effect. Instead of single bubbler we may use more bubbler for our safety and cleaning the hydroxyl gasfor each and every incoming bubbler one back flow check valve has to be placed to avoid the back flow of the water into the gas generatorside. An important caution about the backfire is that we must ensure the water level in the bubbler at all times or otherwise it will lead to back fire explosion because hydroxyl gas is ignited easily.

Figure 3.4: water reservoir and bubbler(M. Mikami, (2011) [12])

3.1.4. Electrolyte and its Catalyst

In hydroxyl gas production the distance between the electrode plates does really matter. For electrodes with more space between the plates tap water wouldn't work. So we used distilled water with a little of the catalysts.

Selection of Catalysts

The catalysts may be pinch of salt or White Vinegar (H_3C-COOH) or Baking Soda ($NaHCO_3$) or Sodium Hydroxide (NaOH) or Potassium Hydroxide (KOH) or Potassium Carbonate (K_2CO_3). Each catalyst has its own merits and demerits. As per the requirement the catalyst is chosen; otherwise it gives more heat with more gas but consumes more DC current from the vehicle battery. Density of electrolyte is directly proportional to current consumption.

Safe Alternatives to Baking Soda

Sodium Citrate which is basically citric acid: A safe food ingredient used in ice-cream, cheese and wine. Possible sources: ice cream/beverage manufacturers, food supplies, etc. You may find it under other names: Citrosodine, Tri-Sodium Citrate, Citric Acid (PURE citric acid, no sugar please!), or Tri-Sodium Salt. Washing Soda is a laundry detergent that might be found under the names of Soda Ash, Laundry Soda, Sal Soda, or Sodium Carbonate. Used as a non-toxic all-purpose cleaner-look in the laundry section of your grocery store.

3.2. Electrical and Electronics

3.2.1. Power Supplies

The material switch constricts electrical system described in the following table 3.2.

Table 3.2: material needed for electrical system of hydroxyl fuel kit

Material	Specification	Quantity
Relay	12V,30amp	1
Fuse	30amp	1
Male and female connecter	2.5mm	10
On/off switch	4 terminal	1
Wire	2.5mm	3m
Wire	3.5mm	1.5m
Fuse box		1

Figure 3.5 shows the circuit diagram of the project

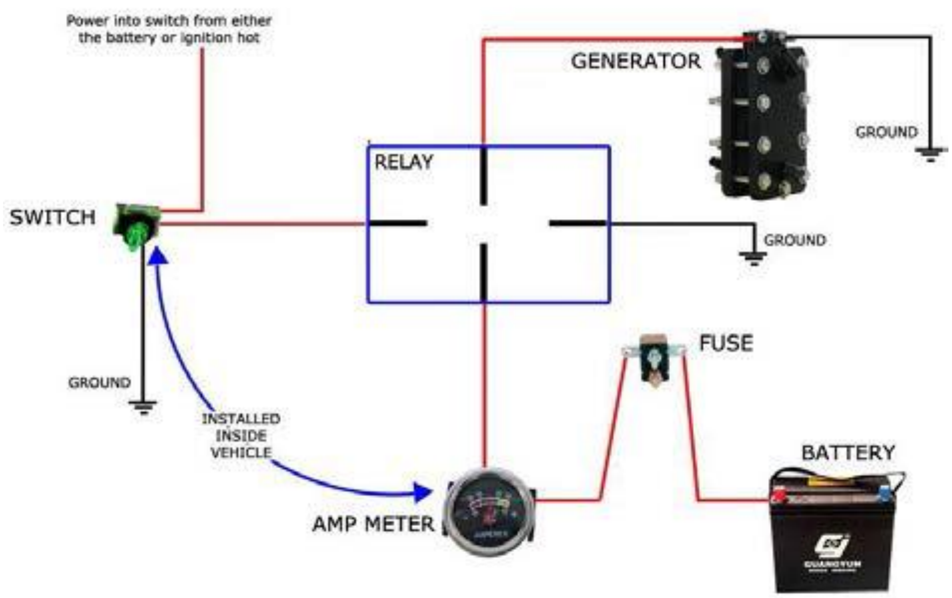


Figure 3.5: circuit diagramof the project

The above circuit diagram shows fuse is connected to battery and then on/off switch is in series with fuse which in turn connected to ammeter then to HHO Dry Fuel cell. And then the gas enters into the Engine as shown in circuit.

3.2.2.Block Diagram of HHO Drycell

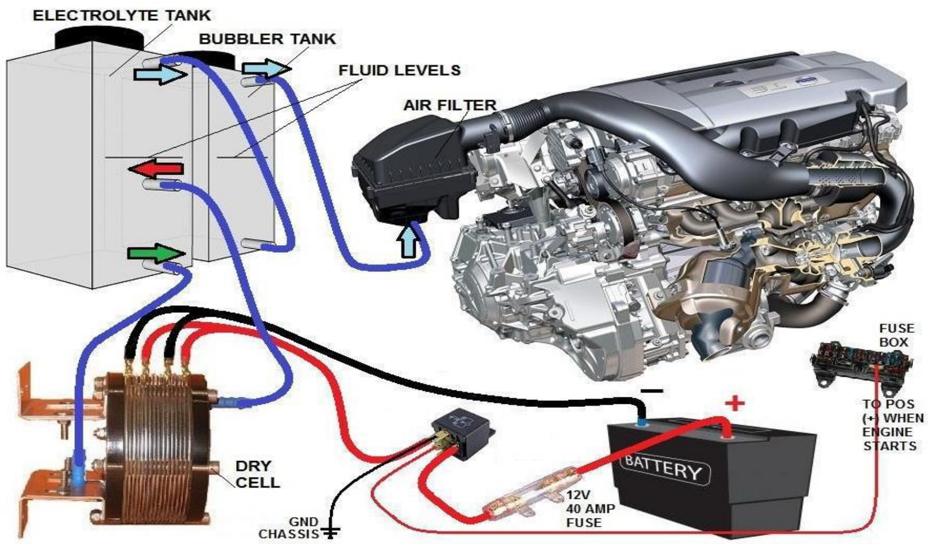


Figure 3.6: Block Diagrams of HHO Dry cell(M. Mikami, (2011) [12])

The block diagram of the HHO dry cell consist a battery of 12 volts connected to the fuse of 40 amps. The fuse is then connected to a switch. An ammeter is kept to measure the readings of the current flowing from the battery to the HHO dry cell. The positive wire from the ammeter is connected to the HHO dry cell and the negative is connected to the car grounding. When the process starts HHO is produced and the gas from the outlet is sent directly to the intake manifold with the help of a silicon pipe. The inlet port is drilled to let HHO gas as shown in the figure 3.6 and 3.7.

Figure 3.7: Modified intake manifold

3.3. Working of HHO Dry cell

When the current starts flowing through the stainless steel plate'selectrolysis process is carried out between the two terminals ofthe plates by which the water molecules get separated as HHOgas. The gas flows through the bubbler tank provided with a nonreturnvalve to prevent the backpressure of gas. From bubbler theHHO gas flows through the P.V.C pipe provided at the outletvalve using the silicon pipe the gas flows to the intake manifold. Water is the most abundant resource on our planet andyou can use it as a fuel. That's Right, a supplementary Fuel from water hydrogen generators have become an essential fuelassistant for internal combustion engine applications. Byconverting water into its primary elements of Hydrogen andOxygen (HHO) and introducing the hydrogen/oxygen gas inconjunction with your regular fuel, our Hydrogen Generator can improve the fuel economy of your engine as wellas drastically lower emissions to exceptionally clean standards.

3.3.1. Working of HHO gas in Engine

In the combustion chamber the Diesel which comes from the fuelinjector gets mixed up with the mixture of air and hydrogen gascoming from the hydrogen dry cell. The hydrogen gas mixed withair enriches the fuel. As the hydrogen gas is highly flammable ithelps in efficient burning of the fuel and removes the carbon deposits inside the cylinder and helps in running a cleaner engine.

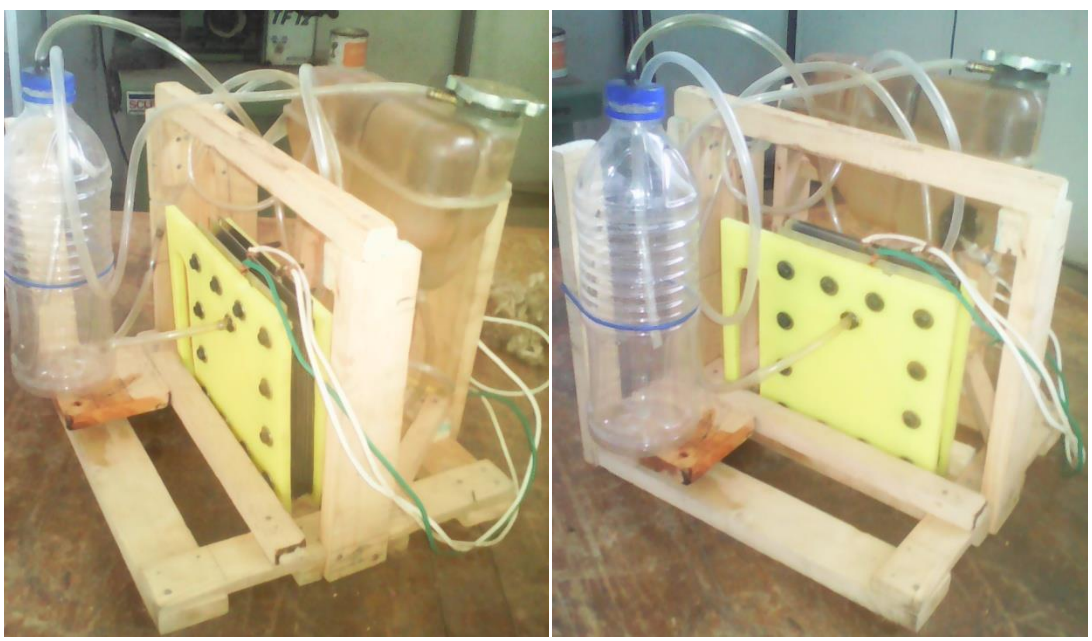
3.3.2. Combustion in Engine

The process is as follows, you start with water and anelectrolyte, and there are many different types. You add current, the H_2O breaks down into H_2& O [we just call it HHO].We introduce it into the engine by use of the engines vacuum.The HHO combines with air and is burnt together in thecombustion chamber. Once burnt, it converts back to H_20 (water).It's now going to absorb the inner heat from the engine and turn into super-heated dry steam. Thenit's pushed out during the exhaust stroke and out the tail pipe.There it condenses back into to water vapour and eventuallycollects back into water. The most amazing part of the process isthat the emissions reduced to exceptionally clean low levels.

3.4. Assembling the component parts

As shown in the figure 3.8 all the component parts are equipped in one holder. The holder has a dimension of$(400 \times 300 \times 400)$mm.The holder is made from wood. It is open not box for cooling of gas generator. At the lower side of the container there is switch box which contain gas outlet, breaker switch, and battery voltage supply. The bubbler and the water container hold the upper part of the container to drive the water down ward using gravitational force. The gas generator and electrical component holds the lower parts of the container. Assembling the component part in one holder has the following advantages:

- It make easier to install and un install hydroxyl gas generator
- It require smaller space to install on the vehicle
- It will be easier to install the kit far from the hot component of the vehicle
- It will be easy to handle



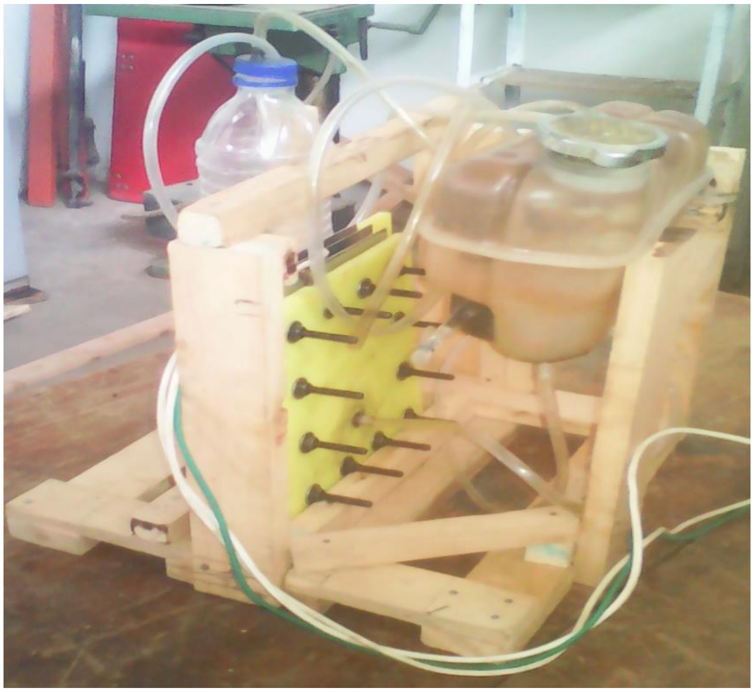


Figure 3.8: assembled part of hydroxyl fuel kit

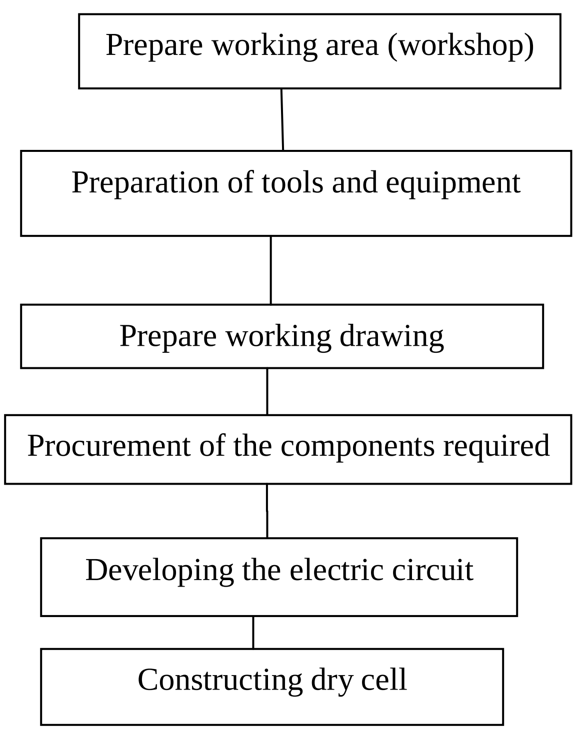
3.5. Design consideration for HHO Gas Generator

The following are the design consideration for HHO generating kit

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

3.6. The procedure of the project

The following figure shows the various steps involved in the project



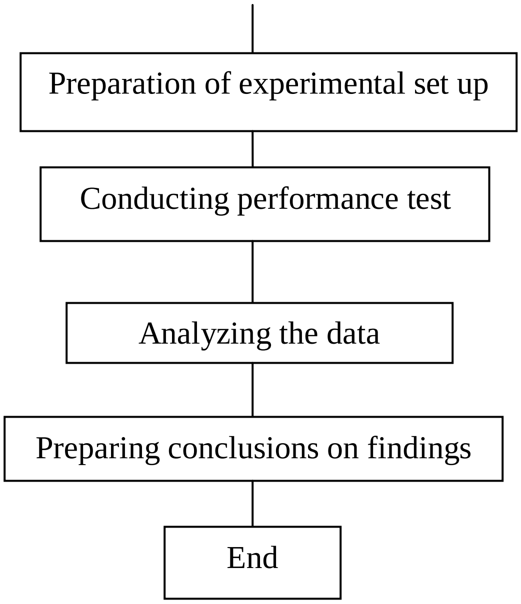


Figure 3.9.Various steps involved in the project

3.7. Analysis of Gas Production

3.7.1. Chemistry

HHO is the stoichiometric mixture of hydrogen and oxygen generated from water electrolysis. Water electrolysis occurs when DC electron current flows from a negative electrode (cathode) to the positive conductor (anode) via an electrolytic solution. Aqueous hydrogen cautions H^+ are attracted to the cathode where they accept electrons and form covalent bonds resulting in H_2 gas generation. The hydroxide anions balance the flow of current in the electrolyte solution and are attracted to positive (anode) conductor, where they release electrons to the anode to form water and covalently bonded oxygen gas or O_2. In this way current is balanced at anode and cathode.

Chemical reaction at anode (positive conductor);

$$2OH^-_{(aq)} \rightarrow \frac{1}{2}O_{2(g)} + H_2O + 2e \ldots\ldots\ldots\ldots(3.1)$$

Chemical reaction at cathode (negative conductor);

$$2H^{+}_{(aq)} + 2e \rightarrow H_{2\,(g)} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.2)$$

The electrolyte allows current to flow with much lower overpotential and allows much higher conductivity than electrolysis in pure water. Typically strong bases are used as electrolytes either sodium hydroxide (NaOH) or potassium hydroxide (KOH).

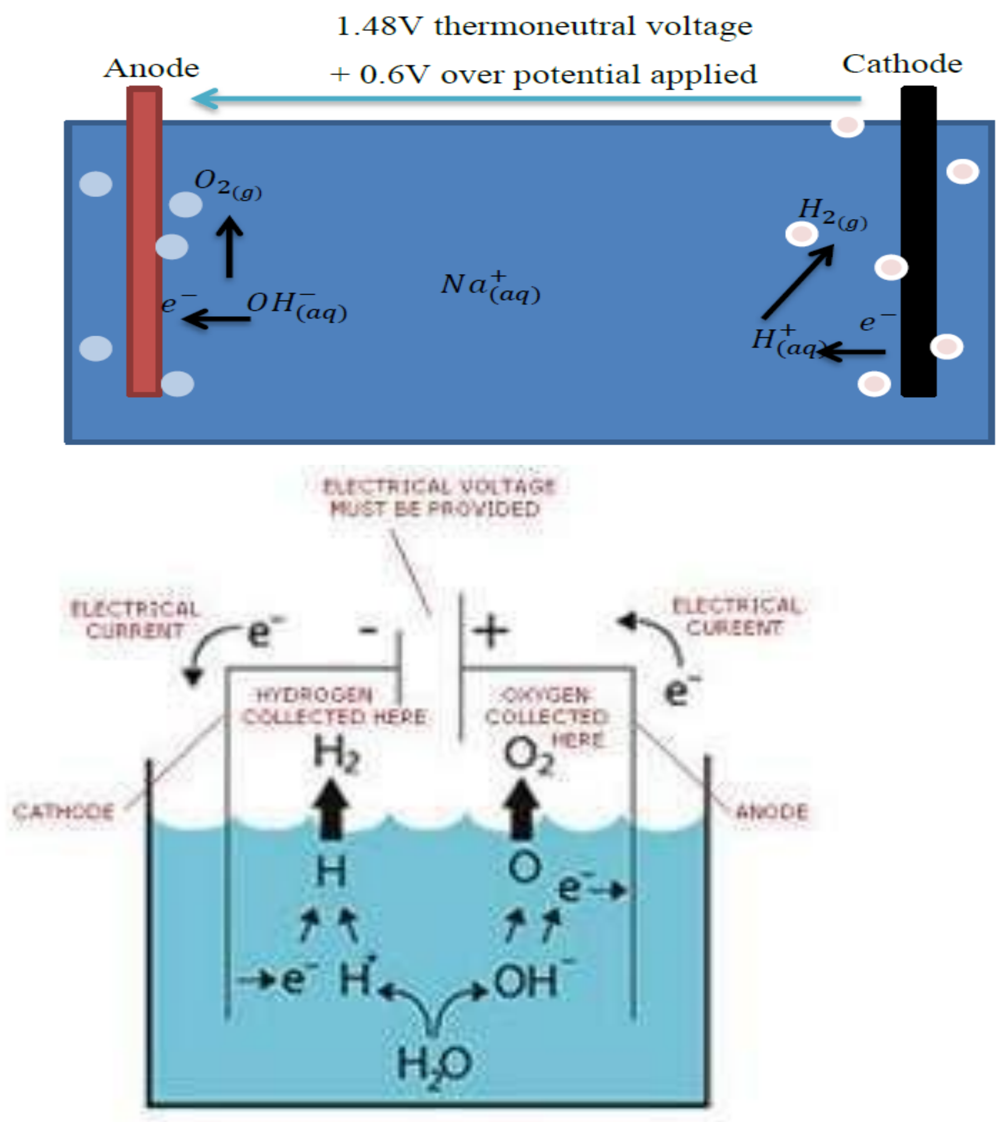


Figure 3.10: Single cell water electrolysis, showing formation of hydrogen gas at cathode and oxygen gas at anode.

1. Small volume of HHO storage:

The hydrogen and oxygen are produced on demand, so the only storage is in the supply lines and the gas void in the electrolyte tank and molecular sieve. The maximum storage/worst case scenario is around 1L stored in the bubbler flash back arrestor. The energy in 1L of HHO could be calculated as the HHV of the stored volume of hydrogen.

Mass of hydrogen in 1L at STP

$$m_{h2} = \frac{p.v.MV}{R.T}$$

$$= \frac{101325 \times 667 \times 10^{-6} \times 2.016}{8.314 \times 298.15} = 55.0mg$$

Where, m_{H_2} is the mass of hydrogen

P is the pressure of air [Pa]

V is volume of gas [m^3]

MW is the molecular weight of hydrogen [g mol^{-1}]

R is the ideal gas constant [J K^{-1} mol^{-1}]

T is the temperature [K]

Energy in 1 liter of HHO in terms of the product of the higher heating value of hydrogen (HHV_{H2});

$$E_{H_2} = m_{H_2} \times HHV_{H_2}$$

$$= 55.0 \text{ x } 10^{-6} \text{ x } 141.86 \text{ x} 10^{3}$$

=7.8 kJ

Where, HHV_{H2} is the higher heating value of hydrogen [J/g]. This is the equivalent to the energy contained in 0.17g of diesel.

In order to quantitate the process of electrolysis, some equations that relate the current needed to obtain a certain volume for a gas have been found. The process for this calculation at room temperature and at 1atm is:

1. Write the half-reactions that take place at the anode and at the cathode.

Anode (oxidation): $2H_2O(I) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

Cathode (reduction): $2H^{+}(aq) + 2e^{-} \rightarrow H_2(g)$

2. Calculate the number of moles of electrons that were transferred.

Knowing:

- ✓ $\text{Amperes } \times \text{time } = \text{ Coulombs}$
- ✓ 96,485 coulombs = 1 Faraday (F)
- ✓ 1 Faraday = 1 mole of electrons

Example:

$$20(\text{amp}) \times 3600(\text{second}) = 72{,}000(\text{colomb})$$

$$72{,}000\text{C} \times \frac{1\text{F}}{96485\text{C}^{-}} = 0.746\text{F}$$

$$0.746\text{F} \times \frac{1\text{mole e}^{-}}{1\text{F}} = 0.746 \text{ mole e}^{-}$$

3. Calculate the moles of hydrogen and oxygen produced using the number of moles of electrons calculated and the stoichiometry's from the balanced half-reactions. According to the equations, 2 moles of electrons produce 2 mole of H_2 and 4 moles of electrons produce 1 mole of O_2 gas.

$$0.746\text{mole e}^{-} \times \frac{2\text{mole of H}_2}{2\text{mole of e}^{-}} = 0.746\text{mole of H}_2$$

$$0.746\text{mole e}^{-} \times \frac{1\text{mole of O}_2}{4\text{mole of e}^{-}} = 0.1860 \text{ mole of O}_2$$

4. Calculate the volume of each gas using ideal gas law (V=nRT/P). Where n:number of moles.

R: Boltzmann constant = 0.08206 (L atm/mol K)

T: temperature in kelvin.

Volume of Hydrogen gas:

$$\frac{(0.764 \text{ mole H}_2)\left(0.08206 \text{ L } \frac{\text{atm}}{\text{mole}}\right)(298\text{K})}{1\text{atm}} = 18.24 \text{ L of H}_2$$

$$\frac{(0.186\ mole O_2)\left(0.08206\ L\frac{atm}{mole}\right)(298K)}{1atm} = 4.548\ Lof O_2$$

These calculations have shown that for a current of 20 amps during a period of 1 hour, the electrolysis of water yields 18.24 liters of hydrogen gas and 4.548 liters of oxygen gas.

3.8. Experimental Set-Up and Procedure

The research work was conducted in a four stroke, DI- CI engine without any modification and withoutneed for storage tanks. The HHO gas produced was mixed with the inlet air after theair filter at the inlet manifold. The diesel engine specification is given in Table 1. The various apparatus andinstruments used for performance testing are multi meter, stopwatch etc.The multimeter was used to measure the voltage and current of the external power sourceand also that of the HHO gas kit while production of HHO gas. Table 4.1 shows the data collected for current required from the power source for different electrolyte per litre (EPL) of electrolytic solution.

Technical specifications of the diesel engine used in this experimental study are shown in Tables and photographs of the chassis dynamometer is demonstrated in Figure 3.11 and 3.12respectively. Effects of hydroxyl addition to the fuel on exhaust emissions and engine performance are investigated. All of the experiments are conducted in Adama Science and Technology University,Automotive Engineering Department Laboratories.

Table 3.3: Technical specification of CI Diesel test engine

No of cylinder	Four cylinder
Type	DI-CI Diesel engine

Engine	3L
Swept volume	2779 cc
Model	LN106L-PRMRS

Figure 3.11 Dieselengine test vehicle

3.8.1 Test Procedure

- Start by checking all connections. Make sure amp meter and inline fuse have been installed.
- Start the vehicle. While it's running, watch for bubbling action inside of the Reservoir/Bubbler. You should be able to see the gas entering the Reservoir/Bubbler tank.
- Now it's time to check how many amps the dry cell is pulling.
- Make the vehicle and the dynamometer for operation
- Start the engine and depress acceleratorpedal to the given engine speed
- Record the brake Power and Traction Force at each corresponding engine speed and calculate torque using the formula

M= torque $M = F \times r$ (Nm)

N= rpm of the engine

The above procedures are conducted for both engine operation with pure diesel fuel and addition of hydroxyl gas. All the resulting data are recorded on the data sheet provided.

Figure 3.12: Chassis dynamometer

Table 3.4: Technical specifications of the chassis dynamometer

Screen Display:	Vehicle speed(Km/h)
	Traction force(KN)
	Power(KW)

Figure 3.13 Operation test

Fuel Calculations:

Fuel consumption measured in liter per hour but quoted in kilograms per hour,i.e(Liter/hour) × Specific Gravity of Fuel = (Kilograms/hour)

$$m_{f=\frac{\text{volume}}{\text{Time}}} \times \text{Specific Gravity of Fuel}$$

$$m_{f} = \frac{v}{t} \times \gamma \left(\frac{Kg}{sec}\right)$$

Where: sp.gr for diesel = 0.84 (kg/L)

From the definition of the specific fuel consumption, we can write:

$$\mathrm{B.S.F.C(Kg/unit\ of\ brake\ power-hour)} = \frac{\text{fuel consumption in(kg/h)}}{\text{brake power(kw)}} \text{(kg/kw.h)}$$

3.9.Safety Precautions

- ✓ Creates serious damage for vehicle as well as human being if it is not properly installed.
- ✓ While installing the hydroxyl kit the installer should use goggles and gloves and other safety equipment.
- ✓ The hydroxyl kit should be installed while the engine in cool condition.
- ✓ Should not store the hydroxyl gas in any form.
- ✓ During the electrolytic preparation use pure water with minimum level of catalyst.
- ✓ Continuously watch water level.
- ✓ Gas tight proof for container and all other accessories should be provided.
- ✓ Pack electrical connection with fuse.
- ✓ Use fire buster to avoid back fire effects.
- ✓ No metallic dust particles should be found inside the hydroxyl generator container.
- ✓ Car battery terminals should be tight and corrosion free.
- ✓ Testing workshop should have firefightingequipment

4. PRODUCT COST ANALYSIS AND MAINTENANCE AND REPAIR

4.1.Introduction

Cost Analysis is the element-by-element examination of the estimated or actual cost of contract performance to determine the probable cost to the manufacturer. The goal is to form an opinion on whether the proposed costs are in line with what reasonably economical and efficient performance should cost. The costs can be compared with actual costs previously incurred for similar work, the cost or pricing data received from other vendors, and independent cost estimate breakdowns.

4.2. Manufacturing Costs

The term manufacturing costs usually refers to material used, direct labor incurred, and overhead incurred in a manufacturing industry. Material used, direct labor, and manufacturing overhead at the time incurred are not expenses; rather they incurred costs. In the manufacturing process, material, labor, and overhead do not expire; rather through manufacturing activity they become transformed from one type of utility to another.

4.2.1. The costs of raw materials and the cost of standard items

The material costs are refer to those materials which are consumed to produce a real components of our machine and the standard item costs are those costs which is purchased from a local markets/they are a finished product. Table 4.1 and 4.2 shows the costs of raw materials and the standard items.

Table 4.1: The costs of raw materials.

No.	Material Description	Specification	Unit	Qty	Unit price		Total price		Remark
					Birr	Cen	Birr	Cen	
1.	Stainless steel sheet	500x1500x0.8 mm	Pcs	01	3000	00	3000	00	
2.	Plastic gasket(tube)	Old tube	pcs	01	20	00	20	00	
3.	Water(electrolyte) tank	3 liter Capacity reservoir	pcs	01	80	00	80	00	
4.	Hard plastic plate	400x250x8mm	pcs	01	100	00	100	00	
Sub Total							3200	00	

Table 4.2 Standard item cost

No	Material Description	Size Required	Unit	Qty	Unit price		Total price		Remark
					Birr	Cent	Birr	Cen	
1.	Hexagonal bolt & nut	M10x45	Pcs	12	15	00	180	00	
2.	level sensor	Small	Pcs	01	35	00	150	00	
3.	Connectors		pcs	20	8	00	160	00	
4.	Epoxy	U.S.A	pcs	02	45	00	90	00	
5.	Strand wire	Ø4mm	M	10	20	00	200	00	
6.	Hack saw blade	18T/inch	Pcs	02	27	00	54	00	
7.	Grinding disk	Dia. 180	Pcs	1	85	00	85	00	
8.	Drill bit	Ø8mm	Pcs	1	10	00	10	00	
9.	Drill bit	Ø10mm	Pcs	1	10	00	10	00	
10.	Flex-tubing	Ø8mm	m	04	10	00	40	00	
12.	On and Off switch	Normal open	pcs	2	50	00	100	00	
14.	Fuse	Glass type 40A	pcs	02	8	00	16	00	
15	Relay	Normal open 40A	pcs	02	55	00	110	00	
Sub-total cost							1205	00	

Total Materials Cost = Cost of raw materials+ Cost of Standard items

= 3200.00Birr + 1205.00Birr

Total material Cost = 4405.00 Birr

4.2.2. Manufacturing Labor cost

Labor is charged at hourly rates that include 30 percent benefits in manufacturing industry. The charge rates are Br 15per hour for unskilled labor and 25.00 per hour for skilled labor. The skilled labor rate is generally used with the machining equipment. A small amount of extra labor is added to allow for downtime for tasks such as making adjustments and maintenance. This is applicable for general manufacturing industry but our labor estimations have been based upon the hours accumulatively spent on the project as technician earning a 150.00 Br per daily expense. To start our cost study we concerned labor expense data from different areas especially in small scale industry around Adama city. As we have seen most of those industries are one daily wage worker paid only 150.00(one hundred fifty Br) as stated on the table below 18.75 Birr per hour. Table 4.3 and 4.4 shows manufacturing labor and assembling labor cost respectively.

Table 4.3: Manufacturing Labor cost

No.	Activity (operation)	Time(min.)	No. of workers	Total Labor time,(hrs)	Cost (Br /hr)	Total cost in Birr
1.	Cutting plates	60	2	2	18.75	37.5
2.	Drilling plates	60	2	2	18.75	37.5
3.	Cutting gaskets	30	1	0.5	18.75	9.38
	Total	150	5	2:30	18.75	84.38

Table 4.4 Assembling labor cost

S.No	Activity (operation)	Time(min.)	No. of workers	Total Labor time,(hrs)	Cost (Br /hr)	Total cost in Birr
1	Assembly of dry cell	120	2	4	18.75	75
2	Construction of all circuit of dry cell	60	2	2	18.75	37.5
Total		180	4	6	18.75	112.5

Total Labor Cost = Labor cost for manufacturing components + Labor cost for assembling components.

Total labor cost =84.38 +112.5=196.88 birr

4.3. Over Head cost

In general overhead expenses are absorbed by the business and factored into the selling price as a percentage of the direct labor cost. They may include indirect costs such as accounting, advertising, depreciation, indirect labor, insurance, planning, legal fees, rent, research and development, repairs, supplies, taxes, telephone, travel, and utilities.

The overhead costs of the project (depreciation and electric consumption costs) are discussed below.

4.3.1. Electrical power consumption cost

It is the cost of electric power needed to machine and weld parts of the project. Electric power is expressed (measured) by a unit watt (w) or kilo watt (Kw).The cost of electric power is expressed in birr per KWH. The electrical machines used and time consumed is indicated below in table 4.5.

Table 4.5 Machines & time consumed

S.No	Electrical power machine	Working time (t) in hr	Power rating (p)in KW	Energy consumed (E) KWH	Total payment in birr
1	Drilling machine	1:00	1.2	1.2	0.828
2	Portable hand grinder	0:30	0.5	0.25	0.173
	Total	1:30	1.7	1.45	1.001

Note: - The electrical power cost for 1KWH is 0.69 Birr, source from (EELPA)

4.3.2. Depreciation costs (refer Table 4.7)

Most plant and equipment assets wear out or become obsolete over the years. Depreciation for each asset is usually calculated separately and is based on four factors:

A. The asset's cost
B. The asset's estimated life
C. The asset's residual value (its book value after being fully depreciated); and
D. The method of depreciation selected

Straight-line Method: This is the simple method mentioned in the definition of depreciation.

This charges an equal amount each year over the life of the asset. The charge for each year will be calculated as follows;

Depreciation, D = (C-S)/N.

Where: - C is an original cost,

S is a salvage value (take 25% initial price) and

N is a useful economic life in years.

Table 4.7 Depreciation cost of different machines

No.	Types of machine used	Life span (year)	Machine price	Deprecation vales / hour	Operation time	Total deprecation value
	Drilling machine	10	30,000.00	1.17	1:00	1.17
	Portable hand grinding machine	8	8,000.00	0.39	1:00	0.39
Total						1.56

4.4. Total cost of the machine

Total cost of Dry cell

- Manufacturing cost:-

    - ✓ Material cost = 4,405.00 Birr
    - ✓ Labor cost = 196.88 Birr
    - ✓ Overhead cost = 1.00 Birr

Manufacturing cost = 4,602.88 Birr

Contingencies: - it is compensation due to some errors and unexpected failure of time in our project it is usually taken as 10% of the manufacturing cost.

Contingency = 10%x 4,602.88 Birr =460.29 Birr

Total manufacturing cost = Manufacturing cost + Contingency

= 4,602.88 Birr + 460.29 Birr

= 5,063.17 Birr

- ❖ Profit: - it is usually taken as20% of total manufacturing cost

Profit =20/100x5, 063.17 Birr

Profit = 1,012.63 Birr

- ❖ Selling price = Profit + Total manufacturing cost

= 1,012.63 Birr +5,063.17 Birr

Selling price =6,075.80 Birr

Our selling price is 6,075.80 Birr, it is cost effective, it is significant to note that the small micro enterprises, industry and particularly the garages and TVET institutions will benefit in knowing the great investment opportunities in using the developing and modifying the systems. The objective of TVET strategy is to minimize import, to transfer technology and also adopt, therefore findings will help the government in coming up with strategies that will reduce fuel importing from foreign countries, this will have positive impact on the country’s economy.

5. RESULTS AND DISCUSSION

5.1. Introduction

Diesel engines are widely used for various applications changing from agriculture to automobiles. Engines are required to be tested mainly for two purposes- firstly, on production line of engines; engines are tested to check the proper operation, output, fuel consumption etc. And secondly, in research of design purposes, where the performance of new design to be evaluated.The aim of this experimental investigation is, to make a spectacular combination of anodes and cathodes in a simply adaptable ambient within the fuel system and to obtain an enhancement in combustion and reduction in exhaust emissions with electrolysis reaction without the need for storage tanks. In this experimental study, instead of pure hydrogen addition to diesel fuel, produced hydrogen gas along with oxygen (hydroxyl gas) is fed to the intake manifolds of a direct injection CI and four cylinderdiesel engine by a HHO system under various loads. Its effects on engine performance characteristics, FC and Current required from power source for different electrolyte per litre (EPL) are investigated.

5.2. The experimental test results

5.2.1.Current required from Power Source for different electrolyte

An increment in production of HHO gas is obtained using catalyst (KOH) compared to distilled water without catalyst as shown in table 5.1.

Table 5.1: Current Required from Power Source for different electrolyte

KOH pellets(EPL)	HHO gas produced by a Dry cell (in lpm)	Current required from power source (A)
10 no.	0.5	4
20 no.	1	8

5.3. Wheel Power and Traction force

An increment in wheel power is obtained with using hydroxyl gas system compared to pure diesel operation. The increase in power is due to oxygen concentration of hydroxyl gas and better mixing of hydroxyl gas with air and fuel that yield enhanced combustion. Also, high laminar flame velocity of hydroxyl gas yields shorter combustion period that provides lower heat losses, much closer to ideal constant-volume combustion which results increased thermal efficiency.

The tractive force and power at the wheel can be converted into engine (brake torque) and brake power by the following formulas

$$\text{Pb} = \frac{Pw}{\eta t}$$

Where: P_b- brake power

Pw- wheel power

ηt - gear box efficiency

$$T_b = \frac{60 \times P_b \times 1000}{2\pi \times N}$$

The vehicle (Toyota Hilux model 3L engine) has a 5 speed transmission with the following gear ratios:

Table 5.2.vehicle gear ratio

Gear	1st	2nd	3rd	4th	5th	Final drive
Gear ratio	3.901	2.432	1.654	1	0.812	4.544
Efficiency	0.80	0.825	0.85	0.87	0.90	0.92

5.3.1. Test result using only diesel fuel and diesel fuel with hydroxyl gas at first gear

It has been observed that using only diesel fuel the maximum power output is obtained at 35Km/h. Also the maximum traction is obtained from 30-35Km/h. The experimental test data using only diesel fuel at first gear are shown on the table 5.3 and figure 5.1 below.

Table 5.3 Tractive force result comparison with and without hydroxyl gas at first gear

Speed(Km/h)	25	30	35	40

Tractive force for pure diesel (KN)	1.7	1.79	1.9	1.65
Tractive force with HHO gas (KN)	1.7	1.80	1.95	1.7

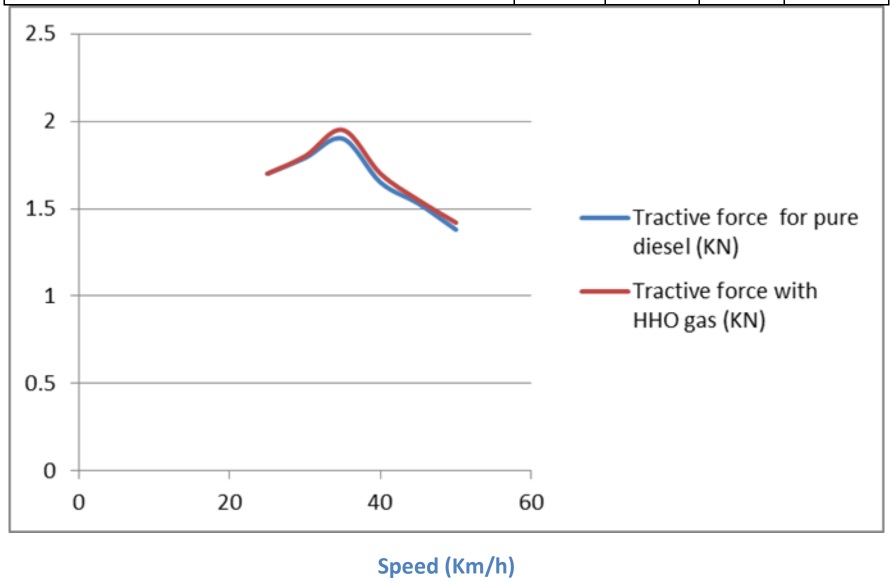


Figure 5.1 Tractive force result comparison with and without hydroxyl gas at first gear

Table 5.5 output power result comparison with and without hydroxyl gas at first gear

Speed(Km/h)	25	30	35	40
Power for pure diesel (KW)	17.5	18.1	19.7	16.3
Power with HHO gas (KW)	17.3	18.2	20.1	17.5

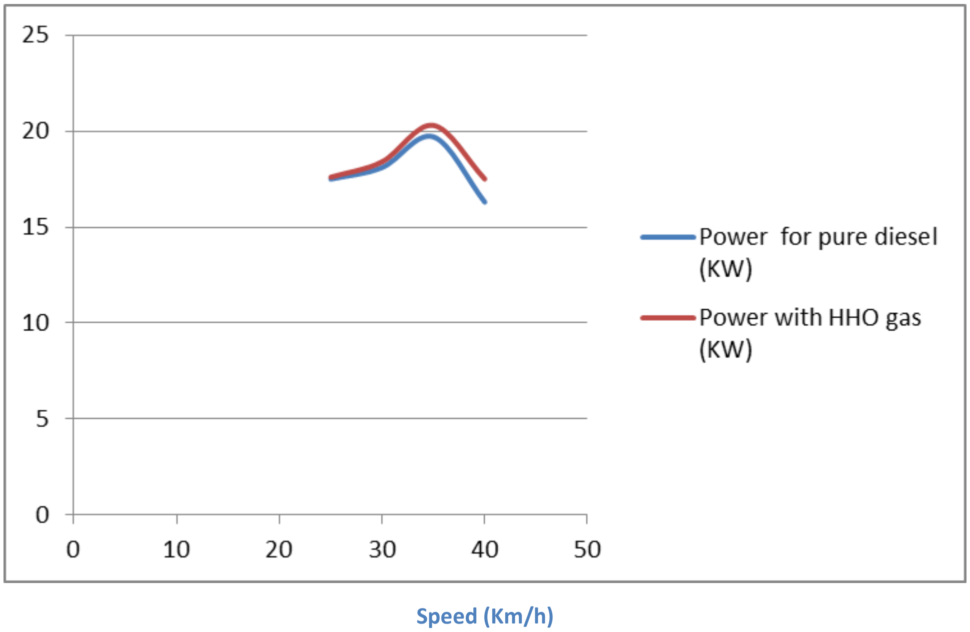


Figure 5.2 output power result comparison with and without hydroxyl gas at first gear

Test results of brake and torque power using only diesel fuel and diesel fuel with hydroxyl gas at first gear are shown on table 5.6 and figure 5.3 and 5.4 below.

Table 5.6 Brake power (Pb) and brake torque (Tb) result comparison with and without hydroxyl gas at first gear

Speed (N) in rpm	Using pure diesel fuel		Using diesel fuel and HHO gas	
	Pb (KW)	Tb	Pb (KW)	Tb
3253	19.02	55.83	21.62	63.46
3903	19.67	48.12	22.75	54.43
4554	21.41	44.89	25.12	52.67
5204	17.71	32.49	21.87	40.13

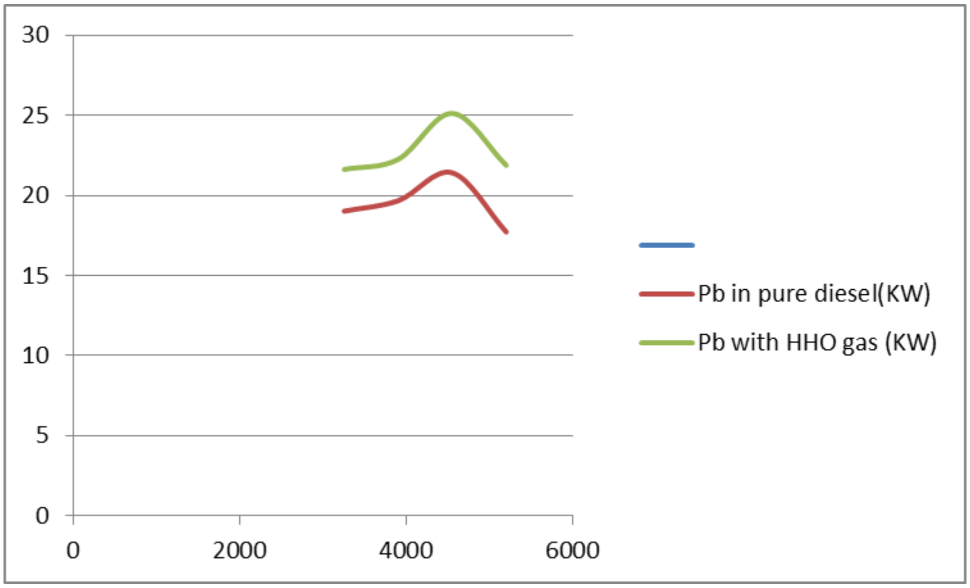


Figure 5.3 Brake power (Pb) result comparison with and without hydroxyl gas at first gear

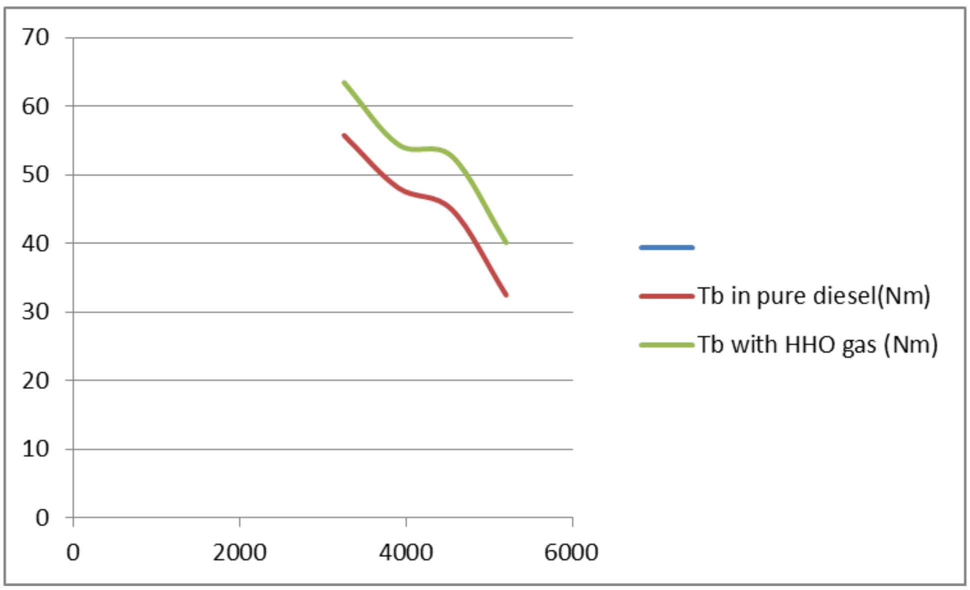


Figure 5.4 Brake torque (Tb) result comparison with and without hydroxyl gas at first gear

The results show that the addition of hydroxyl gas can significantly enlarge the flammable region and extend the flammability limit to lower equivalence ratios. At high speeds (≥35 Km/h) the weakened in-cylinder charge flow and increased residual gas fraction are formed, which block the fuel to be fast and completely burnt at low manifold pressures. Since hydroxyl gas has a low ignition energy and fast flame speed, the hydroxyl gas –diesel mixture can be more easily ignited and quickly combusted than the pure diesel fuel. Thus, improved tractive force at high speeds can be obtained.

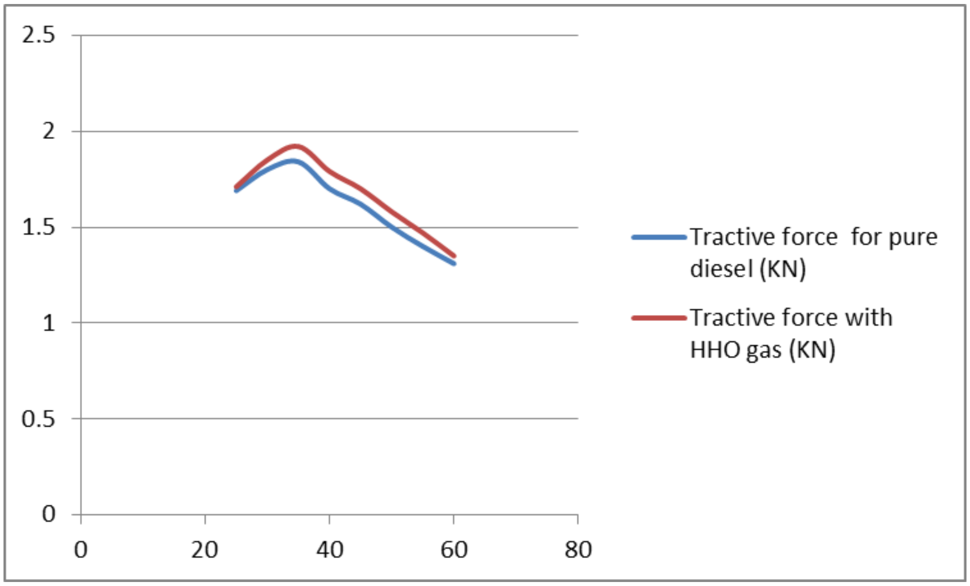
The experimental test result shows that there is a maximum power and tractive force at 35Km/h.

5.3.4 Test result using only diesel fuel and diesel fuel with hydroxyl gas at second gear

Following the same experimental and measurement set up adding hydroxyl gas to intake manifold of diesel engine the maximum power output is obtained at 35Km/h. The test also show the maximum traction force is obtained at 35Km/h. this experimental result are show in table5.7 and 5.8 and figure 5.5and 5.6.

Table 5.7: Tractive force result comparison with and without hydroxyl gas at second gear

Speed(Km/h)	25	30	35	40	45	50	55	60
Tractive force for pure diesel (KN)	1.69	1.8	1.85	1.68	1.5	1.4	1.35	1.31
Tractive force with HHO gas (KN)	1.71	1.85	1.95	1.76	1.57	1.45	1.39	1.35

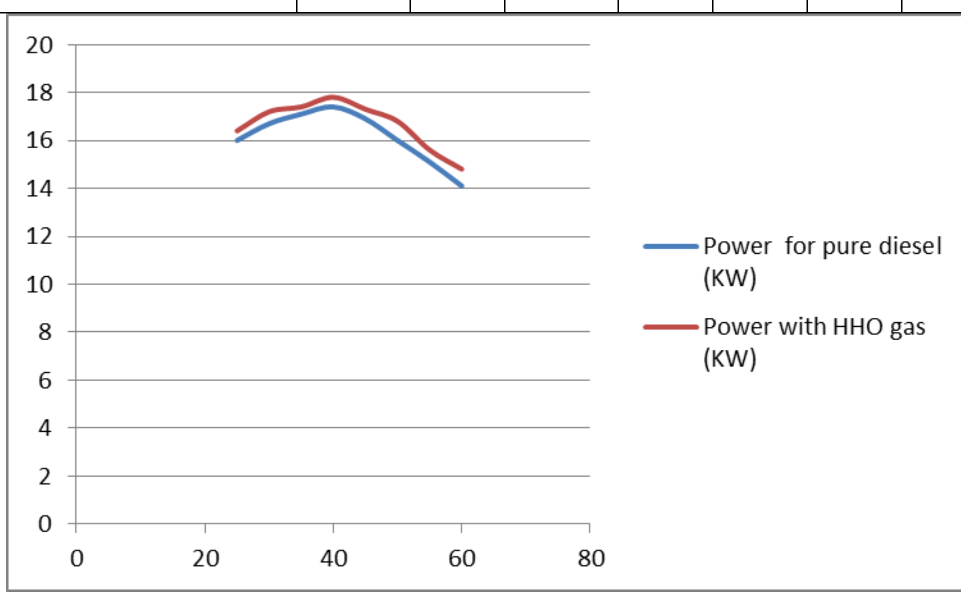


Speed (Km/h)

Figure 5.5 Tractive force result comparison with and without hydroxyl gas at second gear

Table 5.8: output power result comparison with and without hydroxyl gas second gear

Speed(Km/h)	25	30	35	40	45	50	55	60
Power for pure diesel (KW)	16.4	16.7	17.1	17.4	16.8	15.6	15.1	14.5
Power with HHO gas (KW)	16.8	17	17.4	17.8	16.9	15.8	15.3	14.8



Speed (Km/h)

Figure 5.6 output power result comparison with and without hydroxyl gas at second gear

Test results of brake and torque power using only diesel fuel and diesel fuel with hydroxyl gas at second gear are shown on table 5.8 and figure 5.7 and 5.8 below.

Table 5.8 Brake power (Pb) and brake torque (Tb) result comparison with and without hydroxyl gas at second gear

Speed (N) in rpm	**Using pure diesel fuel**		**Using diesel fuel and HHO gas**	
	Pb (KW)	**Tb**	**Pb (KW)**	**Tb**
2028	**19.87**	**93.56**	**20.36**	**95.25**
2433	**20.24**	**79.44**	**20.6**	**80.85**
2839	**20.72**	**69.69**	**21.09**	**70.93**
3244	**21.09**	**62.02**	**21.57**	**63.49**
3650	**19.39**	**50.72**	**20.48**	**53.58**
4056	**18.32**	**44.52**	**19.15**	**45.08**
4461	**18.32**	**39.21**	**18.54**	**39.68**
4867	**17.57**	**34.47**	**17.93**	**35.17**

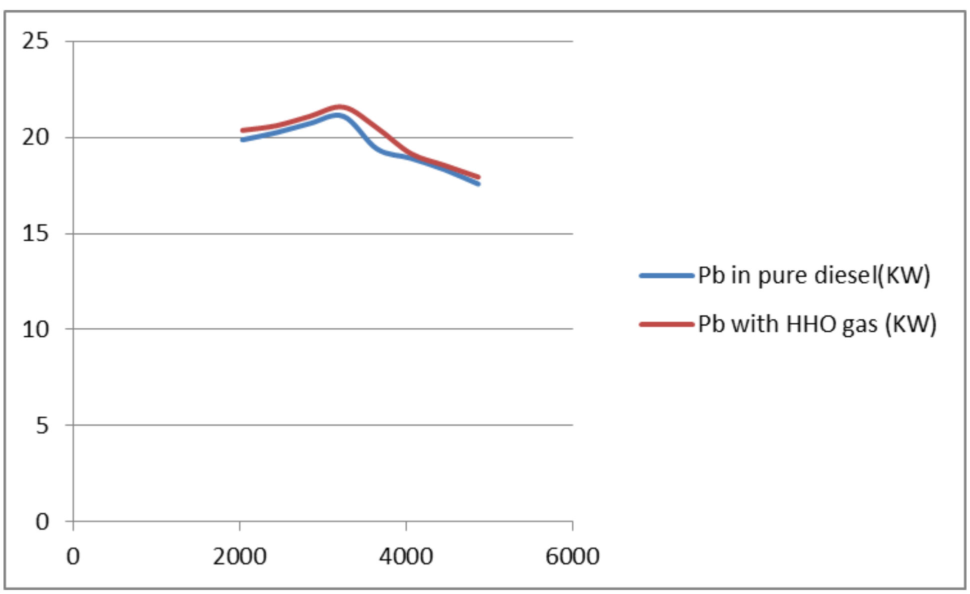


Figure 5.7 Brake power (Pb) result comparison with and without hydroxyl gas at second gear

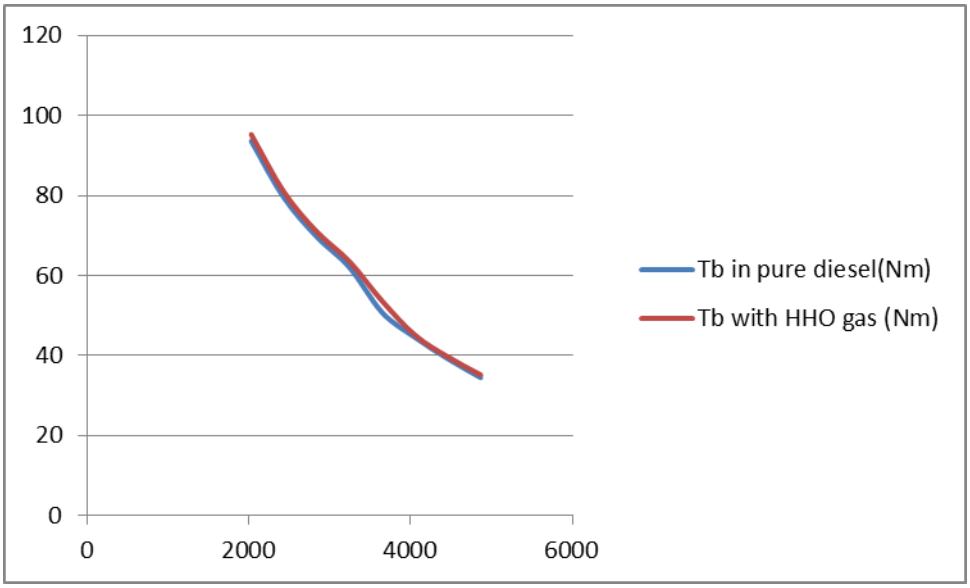


Figure 5.8 Brake torque (Tb) result comparison with and without hydroxyl gas at second gear

The experimental test result shows that there is a maximum power and tractive force at (35-40) Km/h. The addition of hydroxyl gas can significantly enlarge the flammable region and extend the flammability limit to lower equivalence ratios. At high speeds (≥35 Km/h) the weakened in-cylinder charge flow and increased residual gas fraction are formed, which block the fuel to be fast and completely burnt at low manifold pressures. Since hydroxyl gas has a low ignition energy and fast flame speed, the hydroxyl gas –diesel mixture can be more easily ignited and quickly combusted than the pure diesel fuel. Thus, improved tractive force at high speeds can be obtained.

5.3.6 Test result using only diesel fuel and diesel fuel with hydroxyl gas at third gear

Test results of tractive force and wheel power using only diesel fuel and diesel fuel with hydroxyl gas at third gear are shown on table 5.9&5.10 and figure 5.9 &5.10 below.

Table 5.9: Tractive force result comparison with and without hydroxyl gas at third gear

Speed(Km/h)	25	30	35	40	45	50	55	60	65	70
Tractive force for pure diesel (KN)	1.6	1.65	1.69	1.76	1.81	1.62	1.57	1.53	1.5	1.45
Tractive force with HHO	1.61	1.69	1.74	1.78	1.86	1.69	1.65	1.59	1.54	1.46

gas (KN)										

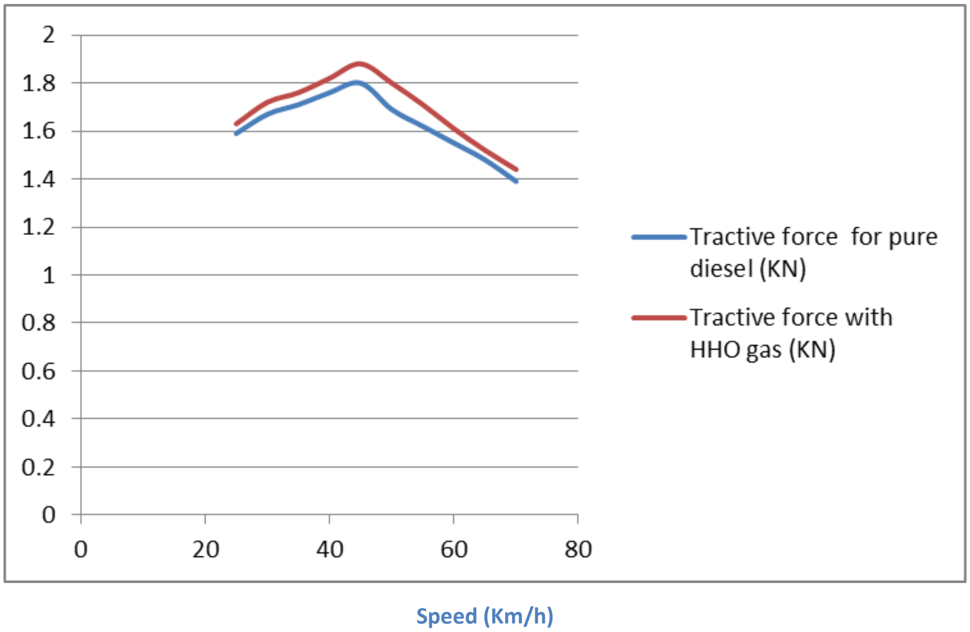
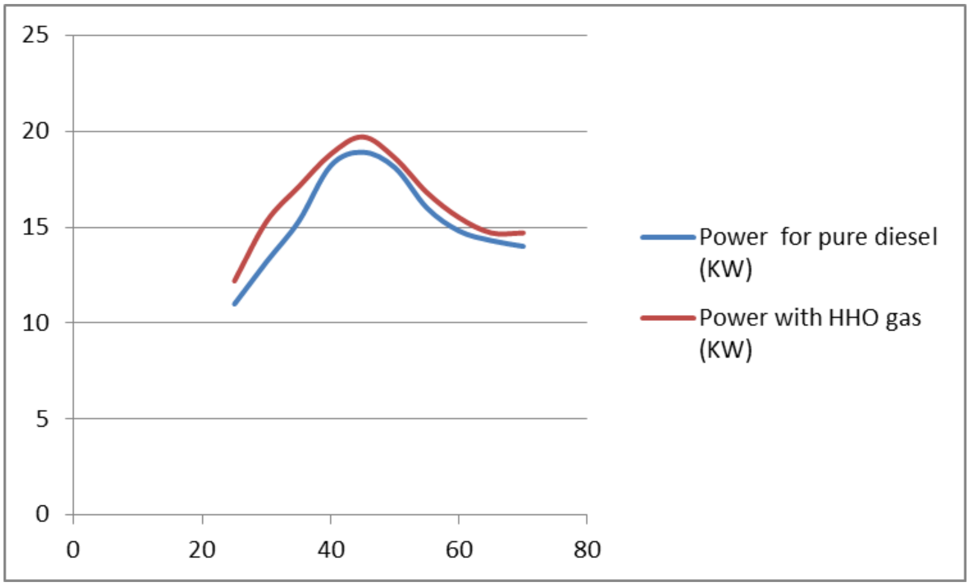


Figure 5.9: Tractive force result comparison with and without hydroxyl gas at third gear

Table 5.10: output power result comparison with and without hydroxyl gas at third gear

Speed(Km/h)	25	30	35	40	45	50	55	60	65	70
Power for pure diesel (KW)	11	13.2	15.3	18.2	18.9	17.1	16	14.6	14.3	14
Power with HHO gas (KW)	12.2	15.3	17.1	18.6	19.4	17.4	16.8	15.5	14.7	14.3



Speed (Km/h)

Figure 5.10: output power result comparison with and without hydroxyl gas at third gear

The experimental test result shows that there is a maximum power (40-45) Km/h and tractive force at (35-40) Km/h. The addition of hydroxyl gas can significantly enlarge the flammable region and extend the flammability limit to lower equivalence ratios. Since hydroxyl gas has a low ignition energy and fast flame speed, the hydroxyl gas –diesel mixture can be more easily ignited and quickly combusted than the pure diesel fuel. Thus, improved tractive force at high speeds can be obtained.

Test results of brake and torque power using only diesel fuel and diesel fuel with hydroxyl gas at second gear are shown on table 5.11 and figure 5.11and 5.12 below.

Table 5.11 Brake power (Pb) and brake torque (Tb) result comparison with and without hydroxyl gas at third gear

Speed (N) in rpm	Using pure diesel fuel		Using diesel fuel and HHO gas	
	Pb (KW)	Tb	Pb (KW)	Tb

1379	12.94	89.59	14.35	99.35
1655	15.53	89.64	18	103.85
1930	18	90.15	20.11	99.45
2206	21.41	92.64	21.88	94.68
2482	22.23	85.50	23.06	88.69
2758	20.11	69.62	20.06	70.86
3034	18.82	59.23	19.76	62.18
3310	17.18	49.56	18.23	52.59
3672	16.82	43.73	17.29	44.95
3862	16.47	40.72	16.82	41.59

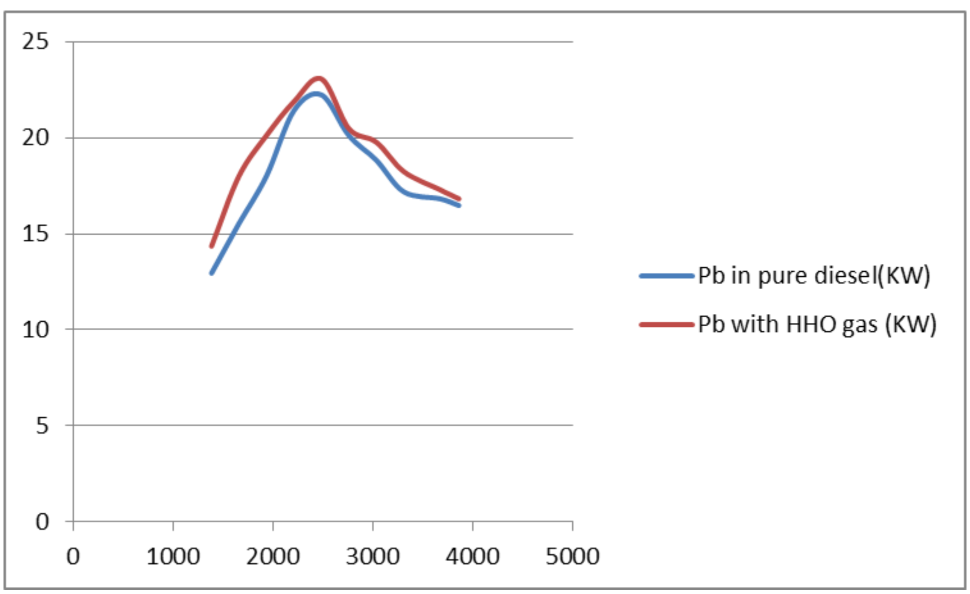


Figure 5.11 Brake power (Pb) result comparison with and without hydroxyl gas at second gear

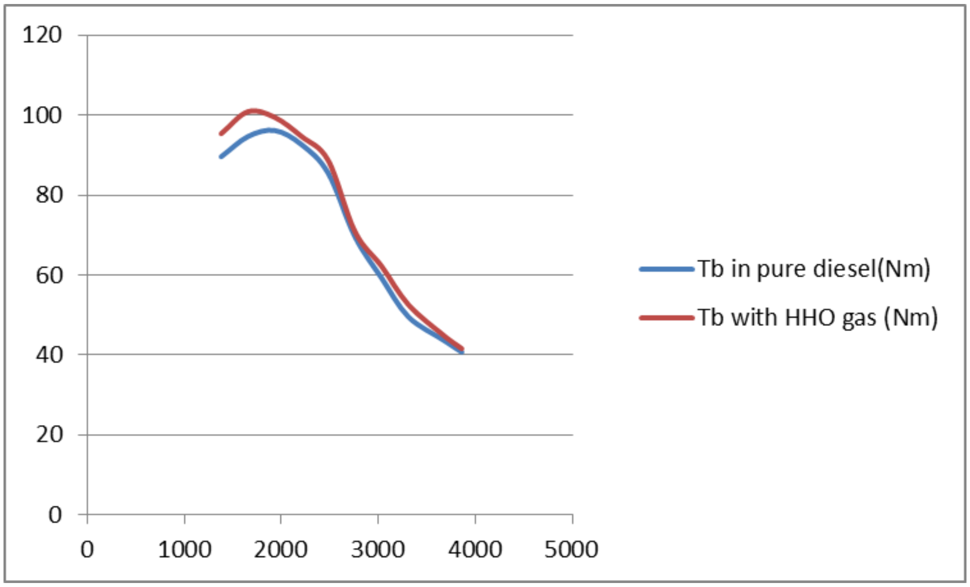


Figure 5.12 Brake power (Pb) result comparison with and without hydroxyl gas at second gear

5.3.8. Test result using only diesel fuel and diesel fuel with hydroxyl gas at fourth gear

Test results of tractive force and wheel power using only diesel fuel and diesel fuel with hydroxyl gas at third gear are shown on table 5.12&5.13 and figure 5.3 &5.14 below.

Table 5.12: Tractive force result comparison with and without hydroxyl gas at fourth gear

Speed(Km/h)	25	30	35	40	45	50	55	60	65	70	75	80
Tractive force for pure diesel (KN)	1.4	1.5	1.6	1.5	1.4	1.3	1.27	1.23	1.19	1.16	1.12	0.9
Tractive force with HHO gas	1.45	1.6	1.65	1.53	1.45	1.32	1.29	1.26	1.22	1.18	1.13	1.11

(KN)												

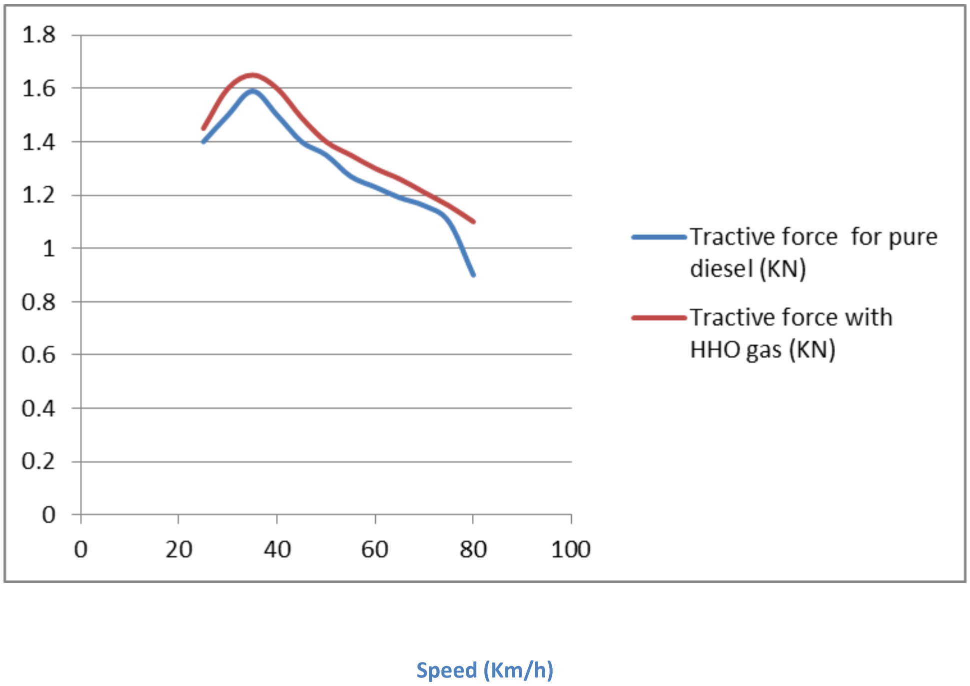


Fig 5.13: Tractive force result comparison with and without hydroxyl gas at fourth gear

Table 5.13: output power result comparison with and without hydroxyl gas at fourth gear

Speed(Km/h)	25	30	35	40	45	50	55	60	65	70	75	80
Power for pure diesel (KW)	10	12.1	14.3	16.2	16.5	16.1	15.2	14.5	14	13.4	12.8	12.1
Power with HHO gas (KW)	10.1	14.3	16.1	17.5	18.7	16.4	15.7	15.1	14.5	13.9	13.1	12.6

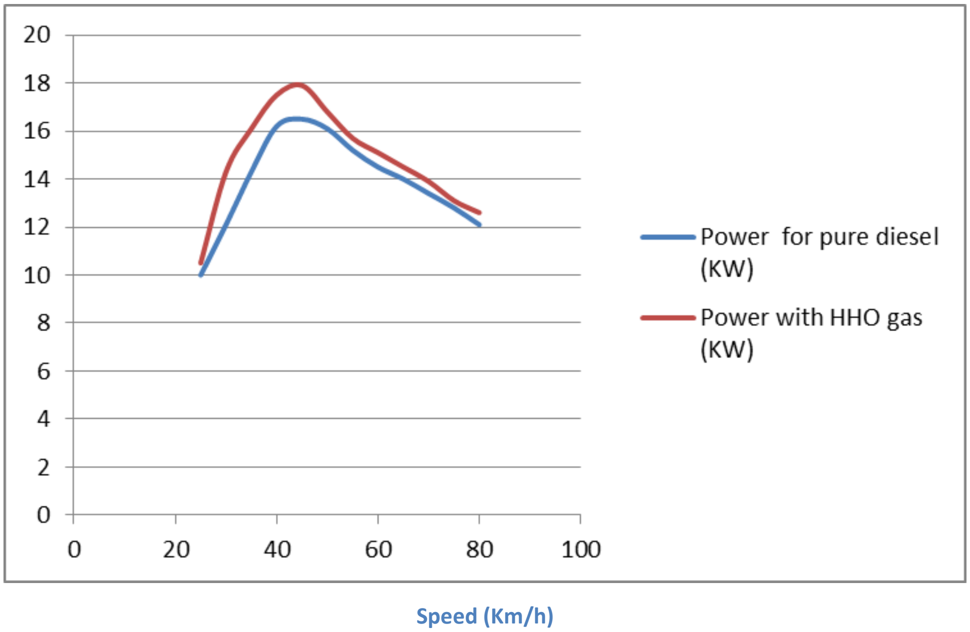


Figure 5.14: output power result comparison with and without hydroxyl gas at fourth gear

The experimental test result shows that there is a maximum power 45 Km/h and tractive force at 35 Km/h. The addition of hydroxyl gas can significantly enlarge the flammable region and extend the flammability limit to lower equivalence ratios. Since hydroxyl gas has a low ignition energy and fast flame speed, the hydroxyl gas –diesel mixture can be more easily ignited and quickly combusted than the pure diesel fuel. Thus, improved tractive force at high speeds can be obtained.

Test results of brake and torque power using only diesel fuel and diesel fuel with hydroxyl gas at second gear are shown on table 5.14 and figure 5.15and 5.16 below.

Table 5.14 Brake power (Pb) and brake torque (Tb) result comparison with and without hydroxyl gas at third gear

Speed (N) in rpm	Using pure diesel fuel		Using diesel fuel and HHO gas	
	Pb (KW)	Tb	Pb (KW)	Tb
834	11.49	131.71	11.60	132.97
1000	13.9	132.73	16.43	136.55
1167	16.43	134.44	18.5	151.38

1334	18.62	133.28	20.11	143.95
1500	18.96	120.7	21.49	136.80
1667	18.5	105.97	18.85	107.98
1834	17.47	90.96	18.04	93.93
2001	16.66	79.5	17.35	82.79
2162	16.09	70.77	16.66	73.41
2334	15.4	63	15.97	65.33
2501	14.71	56.16	15.05	57.46
2668	13.9	49.75	14.48	51.82

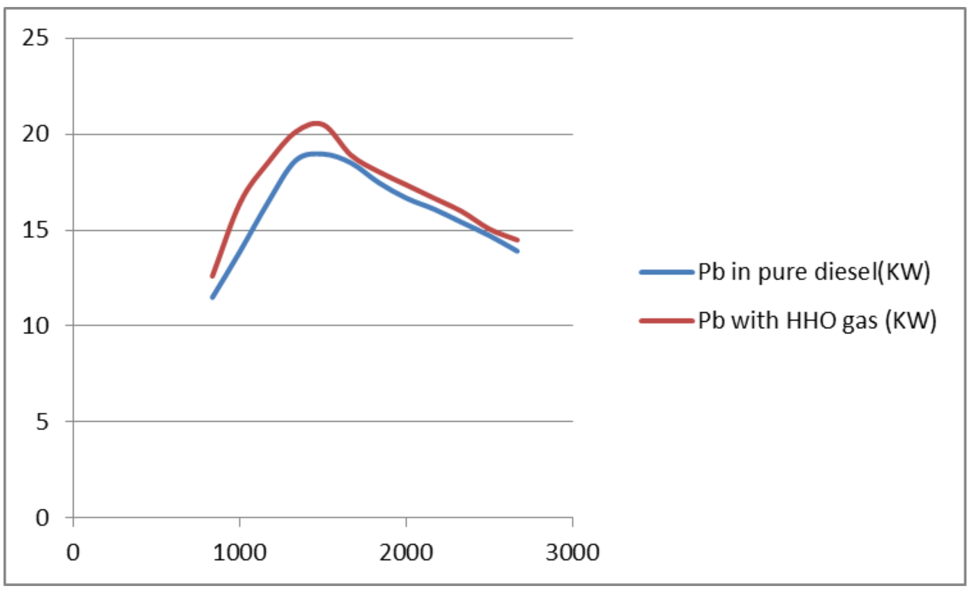


Figure 5.15 Brake power (Pb) result comparison with and without hydroxyl gas at second gear

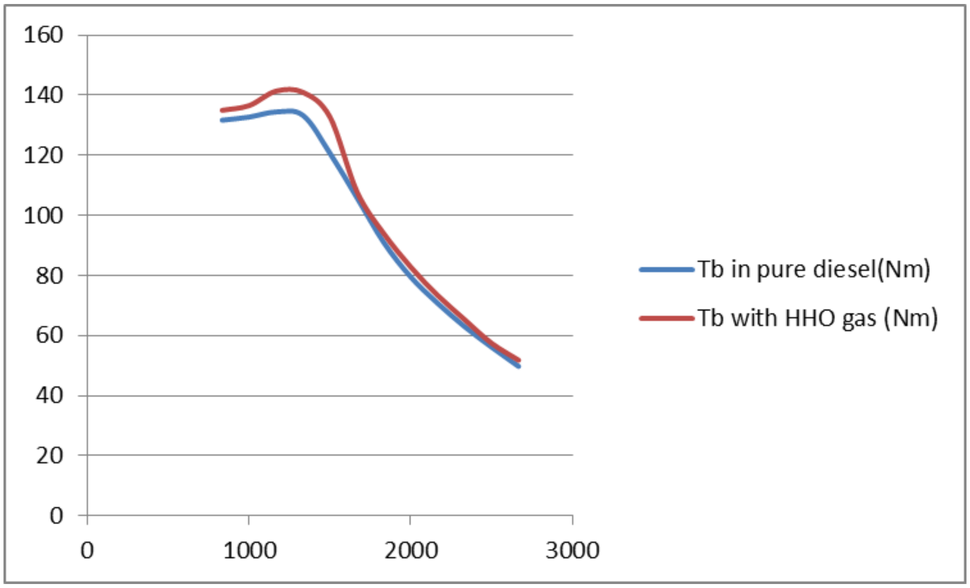


Figure 5.16 Brake torque (Tb) result comparison with and without hydroxyl gas at second gear

5.4. Fuel Consumption (FC)

5.4.1. Comparing time taken for consuming 200ml of fuel with and without HHO in diesel engine

By comparing time taken for consuming 200ml of fuel with and without HHO in diesel engine,the result shows that it takes more time for diesel with HHO gas than pure diesel fuel therefore fuelconsumption is less.

Table5.18. Comparing time for consuming 20ml of fuel with and without HHO in diesel engine

Trial No	Fuel consumed (ml)	Time Taken for pure Diesel fuel (Sec)	Time Taken for Diesel fuel with HHO gas(Sec)
1	200	104	125
2	200	102	127
3	200	102	123
4	200	100	121
5	200	104	125
		Avg= 102.4	Avg=124.2

Under normal conditions or for pure diesel fuel average time taken for 200ml of fuel consumption is 102.4sec

Ordinary fuel consumed i.e. normal conditions 1ml = 0.512sec

This can be converted to lit/hour i.e.

(0.512 X 1000)/3600 = 0.1422lit/hour

Using HHO gas the average time taken for200ml of fuel consumption is 124.2sec

So we save 21.8sec for every 200ml of fuel consumption

21.8sec = 42.578ml

Or we save 42.578ml for every 200ml of fuel

i.e., 21.3% of fuel is saved.

6. SUMMERY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMERY

HHO is composed of two separate elements of Water, consisting of two atoms 1of Hydrogen (H) and one atom of Oxygen (O), thus H2O becomes HHO gas. The most abundant element in the known Universe is Hydrogen, which is the volatile part of this amazing fuel. Oxygen does not burn, but it does support combustion. The technology that is used to extract the two elements from water is known as Electrolysis. Electrolysis of water has been used for experimentation and other industrial processes for over a hundred years. The HHO fuel systems used today are used primarily as a supplemental fuel rather than a replacement for diesel. The electrolyser, a device for producing HHO, is connected to the engine's air intake plenum or duct by a hose and HHO is mixed with the air and gasoline as it is drawn into the combustion chamber. The design is considered an on demand system, meaning that HHO fuel is produced only as is needed, having no storage tank, and stopping when the ignition key is turned off. Fuel mileage is increased because the gasoline burns more completely, producing cleaner exhaust emissions, and you can save money on fuel costs and help the environment by reducing air pollution.

6.2 Conclusions

In the design of our hydrogen generator we are trying to increase fuel efficiency while providing additional power. The hydrogen cell produces oxygen and hydrogen from water through electrolysis. We are trying to minimize the cost by using wildly available materials. However, the cost may go up based on the results of different tests and the goal that we want to reach.Energy must be conserved in one way or other so we are trying to implement this in the future. Using distilled water with a little of the catalyst increase the amount of HHO gas produced.As the speed increases bothpower and tractive force increases up to some point and then decrease. The powerdeveloped by the engine operated on HHO gas is more ascompared with pure diesel. Tractive forceincreases, for engine operated with HHO gas is more ascompared with pure diesel. Total fuelconsumption of the engine, for engine operated with pure diesel is more as comparedwithengine operated with HHO gas, 21.3% of fuel is saved by using hydroxyl gas system. This is the safest method to reduce greenhouse effect in the future by installing this HHO generator in all two and four wheelers vehicles.Generally our project will benefit the environment and society.

6.2. Recommendations

The researchers recommend the following:

- ✓ We recommend conducting further research on controlling mechanisms for the amount of fuel.
- ✓ Further tests by engine dynamometer and exhaust gas analyzer should be done.
- ✓ We recommend conducting further research on performance of diesel engine using dual fuel mode (HHO gas and diesel fuel)
- ✓ No metallic dust particles should be found inside the hydroxyl generator container.

- ✓ The hydroxyl kit should be installed while the engine in cool condition.
- ✓ To perform effective research in automotive sector educational institutes must be equipped with well functional and modern performance testers.
- ✓ Additionally to obtain a smooth curve and minimize error, it is recommendable to take more reading at different engine operation load and speed ranges. Moreover, applying developed software for data analysis is more essential. Using software for data capture and manipulation minimize the time required for laboratory test.

6.3. Educational implications

The overall objective of the national TVET strategy is to create knowledgeable, competent, motivated, entrepreneurial, adaptable, creative and innovative workforce in our country contributing to poverty reduction and social and economic development through facilitating demand driven, high quality technical and vocational education and training, relevant to all sectors of the economy, at all levels and to all people.

The TVET system will ensure options for the articulation of students within the entire educational system on the basis of comparable levels and accreditation of graduation certificates within the unique NQF. Providing vertical and lateral channels between the two streams of formal and non-formal TVET, so that both patterns form an integrated system that allows learners to move from one stream to the other according to specific criteria and enabling lifelong learning (LLL).

Now a day the technology advancing in the field of fuel from conventional diesel fuel into alternative duel fuel which is HHO gas from water electrolysis. This technology advancement is a solution to eliminate the problems of convectional diesel fuel.

Considering this, all automotive sectors including automotive assembly companies, garages, and TVET sectors must take their part and actively play their positive role in the area.

In this regard this project work

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