A REVIEW: THE EFFICIENCY OF USING O_2 AND H_2 (HYDROXY GAS -HHO) GAS ADDITIVES IN A CI ENGINE OPERATING ON DIESEL FUEL AND BIODIESEL

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ABSTRACT

In this review paper we present, apparently for the first time, various measurements in mixture of hydrogen and oxygen called HHO gas produced via new electrolyses (international pending by Hydrogen Technologies Application. A hydrogen vehicle is an fuel vehicle that uses hydrogen as its on-board for motive power. Refer to a personal transportation, such as an automobile, or any vehicle that uses hydrogen in a hydrogen fuel does not occur on Earth, and thus is not an energy source, but is energy. Currently it is most frequently methane or other fossil fuels. However, it can be produced from a wide (wind, solar, or nuclear) that are intermittent, too diffuse or too cumbersome to directly. Integrated wind-to-hydrogen plants, of water are exploring technologies to deliver cast and quantities great enough, to compete with traditional energy. Early hydrogen ignition and supplemental energy consumption for HHO gas production worsen the energy performance of the engine and concentrations of carbon dioxide (CO2) nitrogen oxide (NOx) in when diesel fuel is replaced with biodiesel and HHO gas is added, the indicated efficiency of the engine changes insignificantly; however, concentrations of CO and HC in the exhaust gas and smoke levels are reduced markedly.

Keywords: carbon dioxide (CO2) nitrogen oxide (NOx), HHO.

INTRODUTION:

In the course of the depletion of natural fuel resources, the growth of their prices and the increase of environmental pollution, efforts have been made to improve internal combustion engines, especially with respect to fuel consumption and pollutant emissions levels. In recent years, attention has focused on the benefits of alternative fuels for improving the abovementioned indicators. Key pollutants derived from typically hydrocarbon fuels include unburnt and partially burnt hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx) and harmful particulate matter (PM). More efficient diesel engines are advantageous, as they reduce fuel consumption levels while addressing the “greenhouse effect” . In reducing dependence on fossil fuels and cutting emissions of pollutants and carbon dioxide (CO2), some diesel fuel is replaced with biodiesel (up to 7% by volume) (EN 590:2009 diesel fuel standard). The use of biodiesel fuel enables appreciable reductions of PM, HC and CO emissions without requiring any changes to an engine or to its control. In addition, the energy and environmental performance of an engine and its fuel injection system may require recalibration due to the density, viscosity and cetane number of biodiesel . The use of alternative energy sources (hydrogen) is encouraged through the "Europe 2020" program, which enforces guidelines on the broad use of alternative fuels in Europe. Hydrogen presents properties that are unique from those of hydrocarbon fuels; in addition, this type of fuel does not contain carbon. The most applicable method of hydrogen production involves water electrolysis due to unrestricted access to this raw material and simple modes of production. However, hydrogen use in vehicles creates numerous complications related to hydrogen feeding facilities, safety issues, and vehicle storage. Hydrogen's low density, high pressure requirements for its storage in a vehicle (~70 MPa) and high permeability require the construction of large and particularly tight reservoirs (composed of special steel or composite materials) for keeping hydrogen in a vehicle. One means of tackling said problems could involve the production of hydrogen in vehicles. When hydrogen is used as an additive in internal combustion engines, the C/H ratio decreases, reducing CO2 emissions; in addition, the fuel combustion rate and the quality of combustion remain the same. The toxicity of exhaust gas is reduced to decrease levels of unburnt hydrocarbons and carbon monoxide (CO) in the exhaust gas and levels of smoke; however, NOx emissions grow.

Many companies are working to develop technologies that might efficiently exploit the potential of hydrogen energy for mobile users. The attraction of using hydrogen as an energy currency is that, if hydrogen is prepared without using fossil fuel inputs, vehicle propulsion would not contribute to carbon dioxide emissions. The drawbacks of hydrogen use are low energy content per unit volume, high tank age weights, the storage, transportation and filling of gaseous or liquid hydrogen in vehicles, the large investment in infrastructure that would be required to fuel vehicles and the inefficiency of production processes. Buses, trains, PHB bicycles, canal boats, cargo bikes, golf carts, motorcycles, wheelchairs, ships, airplanes, submarines, and rockets can already run on hydrogen, in various forms. NASA uses hydrogen to launch Space Shuttles into space. There is even a working toy model car that runs on solar power, using a regenerative fuel cell to store energy in the form of hydrogen and oxygen gas.

LITERATURE SURVEY

Production and use of HHO gas in IC engines Subramanian B& Ismail S, International Journal of Hydrogen Energy, 7140-7154, Volume 43, Issue 14, 5 April 2018, HHO gas, which is obtained by the electrolysis of water, is a promising alternative fuel. The state of the art on the use of HHO gas in Internal Combustion (IC) engines is presented in the latter part of the paper. System complexity: The HHO generation system occupies considerable space as it requires power source (battery). Cost: Conventional electrodes made of stainless steel are prone to corrosion and require periodic replacement.

An investigation of the efficiency of using O2 and H2 gas additives in a ci engine operating on diesel fuel and biodiesel, JonasMatijošius, Marijonas, Bogdevičius, ÁkosBereczky, ÁdámTörök. ENERGY, 640-

651, Volume 152, 1 June 2018, A vehicle with a CI (compression ignition) engine, the power of the latter rotates an electric generator to produce a mixture of hydrogen (H2) and oxygen (O2) gas (hydroxyl – HHO, later just HHO) by water electrolysis. Through experimental and numerical modelling investigations of a compression ignition engine and through an analysis of changes in its performance.Engine operating on diesel fuel and biodiesel, the impacts of oxygen and hydrogen gas mixture additives.

Effect of hydroxy (HHO) gas addition on gasoline engine performance and emissions, Mohamed M.EL-Kassaby, YehiaA.Eldrainy, Mohamed E.Khidr, Kareem I.Khidr. Alexandria Engineering Journal, 243-251, Volume 55, Issue 1, March 2016. The objective of this work was to construct a simple innovative HHO generation system and evaluate the effect of hydroxyl gas HHO addition, as an engine performance improver, into gasoline fuel on engine performance and emissions. HHO cell can be integrated easily with existing engine systems. The engine thermal efficiency has been increased up to 10% when HHO gas has been introduced into the air/fuel mixture consequently reducing fuel consumption up to 34%.The concentration of NOx, CO and HC gases has been reduced to almost 15%, 18% and 14% respectively on average when HHO is introduced into the system. The best available catalyst was found to be KOH, with concentration 6 g/L. The proposed design for separation tank takes into consideration the safety precautions needed when dealing with hydrogen fuel.

Effect of HHO gas on combustion emissions in gasoline engines Sa'edA.Musmar, Ammar A.Al-Rousan. Fuel, 3066-3070. Volume 90, Issue 10, October 2011. Reducing the emission pollution associated with oil combustion is gaining an increasing interest worldwide. HHO cell may be integrated easily with existing engine systems. The combustion efficiency has been enhanced when HHO gas has been introduced to the air/fuel mixture, consequently reducing fuel consumption. The concentration of nitrogen oxide has been reduced to almost 50% on average when HHO is introduced to the system. When HHO is introduced to the system, the average concentration of carbon monoxide has been reduced to almost 20% of the case where air/fuel mixture was used (no HHO).

The NOX average concentration has been reduced to about 54%of the case where HHO was not introduced. HC concentration is highly affected by the engine speed and the presence of HHO gas.

Reduction of fuel consumption in gasoline engines by introducing HHO gas into intake manifold. Ammar A.Al-Rousan**.** International Journal of Hydrogen Energy, 12930-12935, Volume 35, Issue 23, December 2010. Brown's gas (HHO) has recently been introduced to the auto industry as a new source of energy. The present work proposes the design of a new device attached to the engine to integrate an HHO production system with the gasoline engine. The use of HHO in gasoline engines enhances combustion efficiency, consequently reducing fuel consumption and thereby decreasing pollution. The optimal size of the FC is when the surface area of an electrolyte needed to generate sufficient amount of HHO is twenty times that of the piston surface area. The FC which can be used is simple, easily constructed, and easily integrated with existing engines at low cost (approximately 15 US dollars for each cylinder).

Using HHO (Hydroxy) and hydrogen enriched castor oil biodiesel in compression ignition engine. Mustafa Ozcanli , MustafaAtakanAkar, Ahmet Calik, HasanSerin. International Journal of Hydrogen Energy, 23366-23372, Volume 42, Issue 36, 7 September 2017. Hydrogen and HHO enriched biodiesel fuels have not been investigated extensively for compression ignition engine. Pure hydrogen addition to CME20 and HHO addition to CME20 were performed by pilot injection method in order to assess the performance and emission properties of a compression ignition engine. Pure hydrogen or hydroxy enriched intake air gas increased power and torque outputs slightly. Specific fuel consumptions of H2þCME20 and HHOþCME20 fuels are significantly reduced according to CME20 and diesel fuel results. Significant CO emission reductions were observed with H2þCME20 and HHOþCME20 usage up to 27% and 21% respectively. NOx emissions were found increased with H2 and HHO additions

HHO Gas with Bio Diesel as a Dual Fuel with Air preheating Technology, R.B.Durairaja, J.Shanker, DrM.Sivasankar, Procedia Engineering, 1112-1119, Volume 38,2012. The increasing industrialization of the world has led the demand of petroleum based fuels. Fossil fuels are obtained from limited reserves. These finite reserves are highly concentrated in certain regions of the world. Reduces the formation of unburned hydrocarbons and reduces the unburned fuel in the combustion chamber. Due to this the combustion process will done in efficient manner and the hydrogen is four times highly effective when compare to ordinary fuels. Due to better evaporation and shorter ignition delay, there is less fuel adhering to the combustion chamber wall and therefore small amount of fuel accumulated in the combustion chamber before ignition is started which may produce low NOx emission as well as low noise and vibration.

A new gaseous and combustible form of water. RuggeroMariaSantilli. International Journal of Hydrogen Energy, 1113-1128, Volume 31, Issue 9, August 2006. In this paper we present, apparently for the first time, various measurements on a mixture of hydrogen and oxygen called HHO gas produced via a new electrolyser which mixture is distinctly different than the Brown and other known gases. The experimental data presented in this paper confirm the existence of a new chemical species whose bond cannot credibly be of valence type. Colleagues may prefer nomenclatures other than “magnecules” to distinguish the new species from molecules, such as “super molecules” due to its predictably easier reception by the scientific community.

Fuel from Water to Run an IC Engine Vehicle, VaibhavKhopade, SurajPrajapati, MayurGavade, RohitSalunke, Prof.A.M.Kasar. International Journal of General Science and Engineering Research, 57-60, Vol 3(2), 2017.To reduce the drawback of petroleum fuels need to do some improvements like use of hydrogen gasoline blend to run IC engine, which don’t have much drawbacks. Use of additive fuel in IC engine will reduce the emission also increase the efficiency of IC engine. After conducting experiment on Honda Activa engine we concluded that mileage of vehicle increases by 15.68%.Wecan conclude that HHO system applied vehicle is more efficient than conventional vehicle in which only petrol is used as fuel.

Design and Fabrication on Hydrogen engine (Waterfuel), P.Balashanmugam G.Balasubramanian. GLOBAL JOURNAL OF ADVANCED RESEARCH, 497-511, Vol-2, Issue-2, 28 February 2015. High level of fuel trapping Fast and complete combustion .Minimal effect from combustion quenching . Minimal parasitic losses from friction and pumping . A hydrogen vehicle is an alternative fuel vehicle that uses hydrogen as its on-board fuel for motive power.

METHODOLOGY

The hydrogen gas is produced by mixing the KOH and water with the help of cathode and anode terminals. This is called Fuel cell arrangement. A fuel cell is an electrochemical cell that converts a source fuel into an electrical current. It generates electricity inside a cell through reactions between a fuel and an oxidant, triggered in the presence of electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate continuously as long as the necessary reactant and oxidant flows are maintained. Fuel cells are different from conventional electrochemical cell batteries in that they consume reactant from an external source, which must be replenished – a thermodynamically open system. By contrast, batteries store electrical energy chemically and hence represent a thermodynamically closed system.

After becoming familiar with the physical characteristics of hydrogen, the engine criteria can be focused on. The initial goal was to design and develop a working hydrogen fueled internal combustion engine without extraordinary modifications. This chapter will discuss basic engine theory with a description and specifications of the engine used in this research. Before an engine is selected, designed, and built some engine theory is important to know. Most engines used in automobiles are known as four stroke engines. The four-stroke cycle means that each cylinder requires four strokes of its piston, or two crankshaft revolutions.

Hydrogen storage is another problem. It takes enormous amounts of space to store liquid hydrogen. Research is in process on how to more effectively store hydrogen in vehicles, but the solution is yet to be found. According to greenliving.com, several companies have invested billions of dollars in the development of efficient hydrogen fuel cells which will carry more hydrogen fuel in a vehicle.

A mixture of hydrogen and oxygen is produced through water decomposition by electrolysis. Water Electrolysis generators can use two types of mechanisms:

1. Splitting water to hydrogen and oxygen gases individually. In an electrolytic cell, O_2 is released at the cathode, and H_2 is released at the anode. Gases released at positive negative electrodes are collected

2. Producing a combustible mixture of H_2 and O_2, i.e., HHO gas.

At a pressure level of 0.1 MPa and at a temperature of 25°C, electrolysis requires the difference of potentials between the anode and cathode to be equal to 1.23 V. When a solution of potassium hydroxide (KOH) electrolyte is used, the voltage between electrodes can reach 2.0–2.5 V, and the current density reaches 2,000 A/m^2 at an electrolyte temperature of 80 °C. Hydrogen and oxygen gases are separated by an ion conductive membrane mounted between the electrodes, and said membrane prevents the gases from blending;

however, it allows OH^- ions to pass through it.

Electrolysis processes :

Electrolyte $2H_2O \rightarrow 2H^+ + 2OH^-$, (1)

Cathode $2H^+ + 2e^- \rightarrow H_2$, (2)

Anode $2OH^- \rightarrow H_2O + ½ O_2 + 2e^-$, (3)
Result $H_2O \rightarrow H_2 + ½ O_2$ ΔHr= 240 kJ/mol.

where ΔHr – enthalpy of the reaction, i.e., theoretical energy consumption necessary for the production of one mol (2 g) of hydrogen. The same amount of energy should be theoretically released through the combustion of one mol of hydrogen. When an HHO mixture ignites, an explosion (extension) and implosion (contraction) of the combustible mixture can occur and result in the production of H_2O, and the energy of this reaction is released as thermal energy. For single-atom molecules, no interatomic bonds should be destroyed prior to the repeated production of H_2O. Thus, the energy level of HHO gas is higher

Using HHO (Hydroxy) and hydrogen enriched castor oil biodiesel in compression ignition engine: The naturally grieved castor seeds were collected from a local area in the Cukurova region of Turkey. Castor oil, which is the raw material for trans esterification, was produced by Soxhlet extraction method. Sodium hydroxide (NaOH) was used as the catalyst. Chemicals were purchased from Merck. Purified methanol was used in the reaction. The transesterification was conducted in a spherical glass reactor which is equipped with are flux condenser, contact thermometer and a mechanical stirrer. The molar ratio of the alcohol and oil was selected to be 6:1.The solution of the catalyst and castor oil were mixed. The reaction temperature was set to 60 _C and kept stable at this temperature for 70 min by stirring. Tanaka brand AKV-202 model a kinematic viscometer was used for the determination of viscosity values. The determination of the pour point of liquid fuels was carried out using a Tanaka MPC-102. Tanaka brand Automated Pensky-Martens device was used to analyze the flash point value of liquid test fuels by Closed Cup Flash Point Test method. The determination of the heating values of Euro-Diesel and CME was carried out using an IKA Werke C2000 bomb calorimeter.

Experimental test rig is illustrated schematically in Experimental set-up In addition, technical specifications of the compression ignition engine and the hydraulic dynamometer. The performance specifications were analyzed using a naturally aspirated 3.6 L, four-cylinder, water-cooled, direct injection CI engine with a glow plug (Mitsubishi Canter). The researcher also connected it to a Netfren mark hydraulic dynamometer with the aim of loading the test engine.
Netfren specific software was used for gathering the data regarding the performance of the engine with the hydraulic dynamometer. The measurement of gas flows was taken before the gas fuels enter the mixing chamber and then the cylinder flow was measured using Alicatvolumetric flow meters. The flow meter was used recording the data. The researcher transferred the retrieved data to host computer using the data logger. All the analyses were carried out at full load conditions between 1200 and 2600 rpm and plotted in 200 rpm increments. An MRU Delta 1600 V gas analyzer was used to determine exhaust emissions through a direct connection to the host computer e the data was collected using specific MRU software. A heavy pressurized (170 bar) tank containing 99.999% pure hydrogen was supplied commercially, whereas HHO was obtained via processing, including water electrolysis. The HHO system can be described as the distilled water electrolysis with an electrolyte of a substance that contains free ions which makes it conductive electrically. In this paper, ion conductivity was supported by KOH (potassium hydroxide).The system consisted of double

parallel connected dry cells with 14 plates in total, a solenoid relay switch, a bubbler, a water reservoir, a constant current Pulse Width Monitor with liquid crystal display (LCD), electrical wires and fittings. An engine battery (24 V) was used for running the HHO generator, which required 30amps to reach 10LPM of ox hydrogen gas. Using mixing chamber, pure oxygen (99.999% pure) and HHO at a constant rate of 10 L/min was mixed with intake air by positioning it in front of the entry to the intake manifold. In Mixing chamber., ‘A’ represents the point where pure hydrogen enters from the tank, ‘B’ represents HHO entry and ‘C ‘represents the test engine intake manifold. The characteristics of hydrogen and HHO are so similar. For this reason, the researcher used HHO instead of H, which demonstrates the fuel properties.

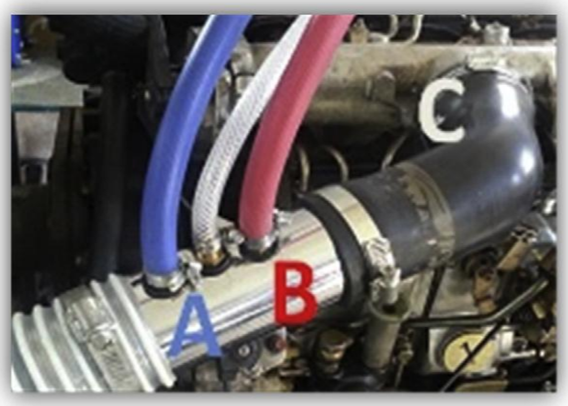


Fig :-2. Mixing chamber.

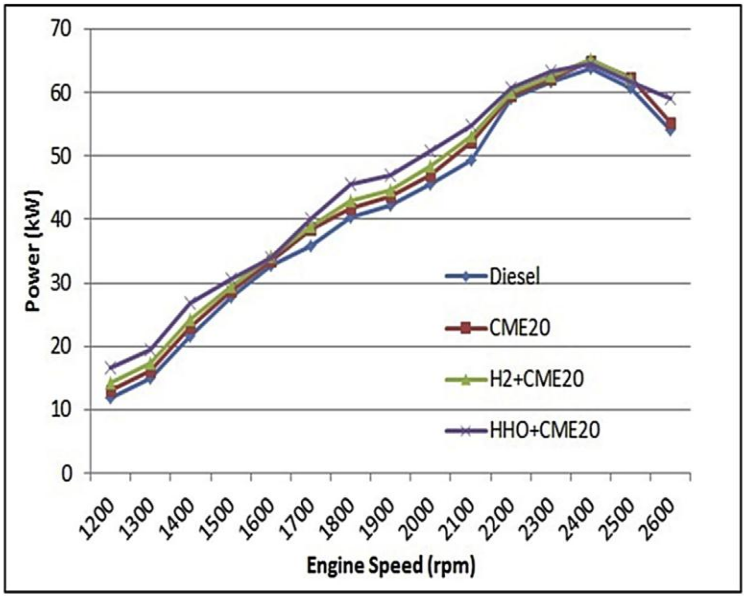
Fuel was distributed to the engine cylinders through a direct injection mechanical fuel pump. The pump was adjusted by a TA 8435 type Toshiba stepping motor driver in order to decrease the fuel level. In order to acquire measurement son the substitution of diesel fuel with higher sensitivity, a stepping motor and stepping motor driver were used. The experiment consisted of four sets of tests. The first set was conducted using diesel fuel, the second with CME20, the third with pure CME20 enriched with hydrogen and the fourth set with CME20 fuel enriched with hydroxy gas (HHO).Approximately 10 min before each test, the engine was started in order for it to reach steady state conditions. All the experiments were replicated three times in order to minimize the experimental errors and increase the accuracy.

TEST 2 - Hydraulic dynamometer specifications.
Brand -Netfren
Torque range- 0-1700 Nm
Speed range- 0-7500 rpm
Body diameter -250 mm
Torque arm length- 250 mm
Torque - 295 Nm @ 1800 rpm

Engine performance and exhaust gas emission subsections. This study aimed to analyze the effects of pure hydrogen and hydroxyl (HHO) gas added to a castor oil methyl ester-diesel fuel blend. Intake air was improved with10 L/min of H_2 and HHO in front of the intake manifold, and no modifications were made to the test engine. The effects ofCME20, HHOþCME20 and H_2þCME20 on the engine performance.

Brake power output versus engine speed for the test fuels. presents the brake power measurements in comparisons engine speed. It was observed that the use of HHO enrichedCME20 fuel produced higher outputs, which provided an average improvement of 4.3% compared to diesel fuel results while pure hydrogen enriched CME20 fuel resulted with an average increase of 2.6%. This increment may be explained by not only extra oxygen content of biodiesel.

GRAPH:- 1.Brake power output versus engine speed for the test fuels.



Hydrogen is stronger in terms of the power to heat. Its higher flame speed is faster than the traditional liquid fuels that can lead a better combustion efficiency. Therefore, these two hydrogen enriched fuels in the present study exhibited higher brake torque results than neat diesel fuel and CME20 as shown in Torque output versus engine speed for the test fuels.

Fuel from Water to Run an IC Engine Vehicle. When electricity flows between two metal conductors that are immersed in water, the water molecule is broken down into its two basic atoms - Hydrogen and Oxygen; through a process called Electrolysis of Water. This electricity is DC (direct current) flowing from the negative Cathode to the positive Anode (like from a battery). Normally water by itself is like an insulator and will not conduct DC electricity, so to make this happen we have to add a little catalyst, called an "Electrolyte". The electrolyte allows current to flow between the -ve side and the +ve side of the plates.5% KOH is added into the water which acts as electrolyte solution.

Plate type HHO generator having plates of 316L stainless steel. The generator is comprised of a plate stack of steel plates, separated by gaskets that go around the perimeter of each plate, with holes drilled in each plate for the electrolyte to flow from one chamber to the next. The stack is not immersed in a liquid bath.

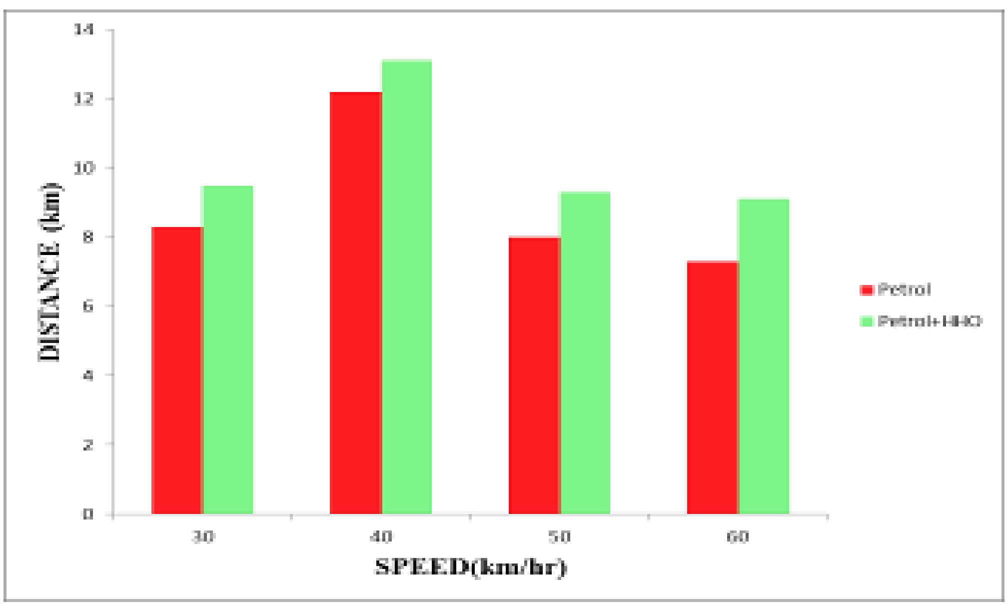
Brute force method is used for supply the energy to the generator in which the output of battery is directly connected to the input of system.

HHO generator system with carburetor. In this assembly the two tanks viz. water tank (containing electrolyzer) and bubbler tank is connected. Output of water tank is fed input to Bubbler tank. Electrolyzer took input electrolyte solution from water tank and electrolyze is connected with battery supply. As soon as the battery supply is ON the reaction getting started and HHO gas is generated which is further supplied to bubbler tank. HHO gas is then supplied to air intake of carburetor, which will further mixed with Petrol and then goes to combustion chamber.

For finding mileage of vehicle we took 200 ml of petrol to run vehicle on fixed defined path without and with HHO generator for given fuel the observations are noted as follows:

Table 1: Mileage test

Speed	Distance covered (Without HHO)	Distance covered (With HHO)
30	8.3 km	9.5 km
40	12.2 km	13.1 km
50	8.0 km	9.3km
60	7.3 km	9.1 km

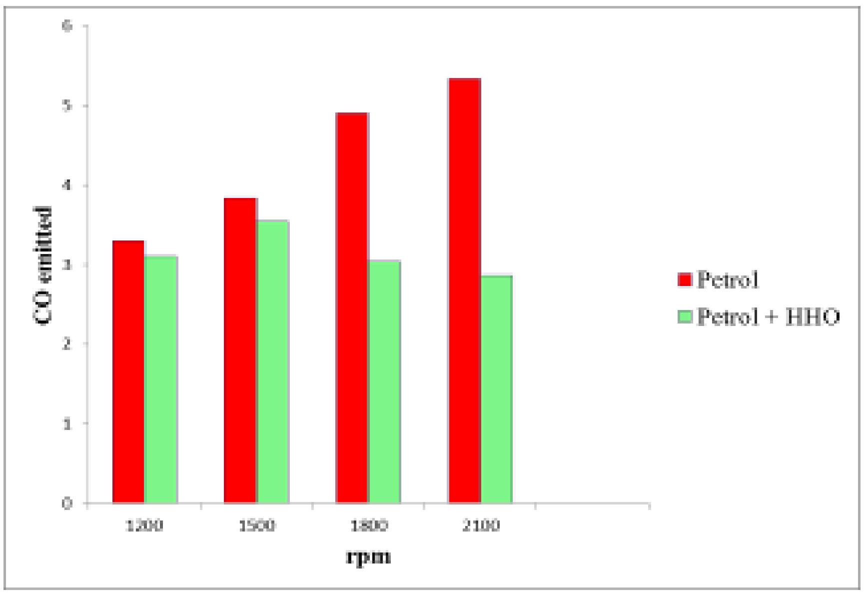


GRAPH:-2.Speed Vs Distance

Above graph shows, speed (km/hr) vs distance traveled (km) characteristics. When we added HHO gas with petrol, the distance travelled by the model vehicle is increased.

Table 2 Emission test (a)

Speed (rpm)	CO	CO_2	HC
1200	3.3	7.8	445
1500	3.84	11.7	1393
2100	4.9	12.1	824
2400	5.33	12.3	438



GRAPH:-3.Speed Vs Emission

Above graph shows, speed (rpm) vs CO emission (%volume) characteristics. In case of Petrol as fuel, CO emission increases as rpm increases. In case of HHO blended fuel, CO emission reduced. It is due to clean burning of charge entering into combustion chamber.

DISCUSSION

A vehicle with a CI (compression ignition) engine, the power of the latter rotates an electric generator to produce a mixture of hydrogen (H2) and oxygen (O2) gas (hydroxyl – HHO, later just HHO) by water electrolysis. Through experimental and numerical modeling investigations of a compression ignition engine and through an analysis of changes in its performance. Engine operating on diesel fuel and biodiesel, the impacts of oxygen and hydrogen gas mixture additives.

High level of fuel trapping Fast and complete combustion .Minimal effect from combustion quenching. Minimal parasitic losses from friction and pumping. A hydrogen vehicle is an alternative fuel vehicle that uses hydrogen as its on-board fuel for motive power. The physical characteristics of hydrogen can have a disadvantage when using hydrogen as a fuel. Equivalence ratio can have a dramatic effect on pre-ignition. Despite hydrogen's high equivalent octane rating its wide flammability limits cause many problems with premature ignition. Reducing hotspots in the combustion chamber and better control algorithms may overcome these disadvantages and enhance the performance of a hydrogen fueled engine.

Hydrogen and HHO enriched biodiesel fuels have not been investigated extensively for compression ignition engine. Pure hydrogen addition to CME20 and HHO addition to CME20 were performed by pilot injection method in order to assess the performance and emission properties of a compression ignition engine. Pure hydrogen or hydroxy enriched intake air gas increased power and torque outputs slightly. Specific fuel consumptions of H2þCME20 and HHOþCME20 fuels are significantly reduced according to CME20 and diesel fuel results. Significant CO emission reductions were observed with H2þCME20 and HHOþCME20 usage up to 27% and 21% respectively. NOx emissions were found increased with H2 and HHO additions.

FUTURE SCOPE

1.) The use of HHO in gasoline engines enhances combustion efficiency, consequently reducing fuel consumption and thereby decreasing pollution.
2.) The fuel technology is extensible for large and small scale standalone systems. The digital controllers for shunt active power filter, The digital controller using Field Programmable gate Array can be designed as an internal part of standalone molecules of fuel cells so as to develop automated FC.
3.) In the future, when the cost of fuel cells reduce because of its development , the FCPS can be modeled for use in any size of irrigation system adequate suction heads.
4.) FC is a fuel supply device containing several parts that demonstrate the real possibility of how hydrogen can be used as a 100% clean fuel for cars in future.
5.) The combustion efficiency has been enhanced when HHO gas has been introduced to the air/fuel mixture, consequently reducing fuel consumption.
6.) The FC which can be used is simple, easily constructed, and easily integrated with existing engines at low cost (approximately 15 US dollars for each cylinder).
7.) Hydrogen is a fuel with heat content nearly three times that of gasoline. From our work we experimentally found out that the efficiency of an IC engine can be rapidly increased by mixing hydrogen with gasoline. Hydrogen is the Key to a Clean Energy Future.

CONCLUSION

Through experimental of a compression ignition engine and through an analysis of changes in its performance, for an engine operating on diesel fuel and biodiesel, the impacts of oxygen and hydrogen gas mixture additives (*VHHO* = 3 l/min) on the energy and environmental performance of the engine were established. HHO volumetric concentrations in the air decrease from ~0.18% to ~0.14%, the hydrogen mass concentration in the combustible mixture decreases from ~0.40% to ~0.13%, and hydrogen energy concentrations in the fuel mixture decrease from ~1.1% to ~0.4%. At a 25% load and at *n* = 1900 rpm, the HHO gas additive spurs an increase in the indicated specific fuel consumption of up to 2% and a reduction of engine indicated efficiency. Through HHO gas use, an increase in the cylinder pressure by the end of the compression stroke period was achieved. From numerical models of the engine operation cycle, it was determined that said pressure increases of the established value are achieved due to the high temperatures reached (~500 K) when hydrogen in HHO gas starts to combust. In this work, FC for HHO gas generation was designed, manufactured and tested. The generated HHO gas was introduced to the air stream just before entering the carburetor of a Honda G 200 engine. The following conclusions can be drawn: 1. The use of HHO in gasoline engines enhances combustion efficiency, consequently reducing fuel consumption and thereby decreasing pollution. 2. The optimal size of the FC is when the surface area of an electrolyte needed to generate sufficient amount of HHO is twenty times that of the piston surface area. Also, the volume of water needed in the cell is about one and half times the engine capacity.3. The FC which can be used is simple, easily constructed, and easily integrated with existing engines at low cost (approximately 15 US dollars for each cylinder).Pure hydrogen addition to CME20 and HHO addition to CME20 were performed by pilot injection method in order to assess the performance and emission properties of a compression ignition engine. Significant CO emission reductions were observed with H2þCME20 and HHOþCME20 usage up to 27% and 21% respectively.

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