Effect of Hydroxy (H_2 & O_2) Gas Addition on Gasoline Engine Performance and Emission with variable Compression Ratio

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Abstract— The reserve of petroleum over the world is limited. It is very important to save petroleum fuels or find some substitutes. The oxygen enriched hydrogen-HHO gas was produced by the process of water electrolysis. Hydroxy gas was produced by the electrolysis process of different electrolytes (KOH, NaOH, and NaCl) with various electrode designs in a leak proof Plexiglas reactor (hydrogen generator). This concern with the effectiveness of oxygen enriched hydrogen-HHO gas addition on performance and combustion characteristics of a SI engine with variable compression ratio. The effect will be shown on the SI engine of the brake power, brake specific fuel consumption, un-burn hydrocarbon, NOx emission, carbon dioxide, and sscarbon monoxide with the use of HHO and a variable compression ratio.

Key words: HHO, Oxygen Enriched Hydrogen-HHO Gas

I. INTRODUCTION

As we know that the sources of petroleum fuels are limited and it will deplete soon in the future. Also use of conventional fuel in engine increase CO, HC, Nitrous Oxides and particulate matter into the atmosphere and this causing global problems such as the greenhouse effect, ozone layer depletion, acid rains and pollution. This encourages engineers and researchers use an alternative fuel in the engine .Without any dramatic change in engine design.

In addition to rules for emission regulations are creating a need for alternative fuels. An alternative fuel must be technically feasible, economically competitive, and environmentally easily available. Numerous potential alternative fuels have been proposed, including biodiesel, methanol, ethanol, hydrogen, boron, natural gas, liquefied petroleum gas (LPG), electricity, and solar fuels.

One of these alternative fuels, hydrogen, has the highest specific energy content of all conventional fuels and is the most abundant element in the universe. Hydrogen will be a key contribution to sustainable development, because in the future it may be produced in unlimited quantities using renewable energy sources.

A. *Property of Hydrogen*

Sr. No	Property	Hydrogen
1	Flammability limit in air at 20^0 760 mm HG (by % volume)	4.1-75.6
2	Minimum ignition energy in air (mj)	0.017
3	Laminar flame speed at NTP(m/s)	1.90
4	Adiabatic flame temperature (K)	2318
5	Auto ignition temperature (K)	848-853
6	Quenching gap at NTP(mm)	0.64
7	Stoichiometric air fuel ratio (kg/kg)	34.3
8	Combustion energy at kg	3.37
9	Kinematic viscosity (mm/sec^2)	110
10	Thermal conductivity (MW/mk)	182
11	Molecular mass (kg/kmol)	2.017
12	Octane number	>130
13	Theoretical air fuel ratio	34.32
14	Lower heating value (mj/m^3)	10.22
15	Lower heating value (kj/kg)	119600
16	Higher heating value (mj/m^3)	12.10
17	Higher heating value (kj/kg)	141600
18	Normal boil point	20.3

Table 1: Property of Hydrogen

B. *Literature Review*

Shashikant jadhav [1] “This study is carried out to investigate the effect of HHO gas addition on engine performance and emission and it with pure gasoline fuelled engine. Above investigation conclude that

1) At full load, fuel consumption is reduced about 18.87 % in HHO supplemented petrol engine than the normal petrol engine. This is because of better combustion; the uniform mixture of air especially the oxygen of original ratio makes it overall leaner mixture and HHO gas assists gasoline during combustion process and complete combustion is due to its property high flame speed and wide flammability range.
2) Engine brake thermal efficiency is improved after hydrogen enrichment. It is increased by 1.42% at 1 ampere 12v, 2.43% at 2 ampere 12v and 3.72% at 3 ampere 12v at full load condition.
3) Brake specific fuel consumption of engine decreases from 0.4782 Kg/kw.hr to 0.385 Kg/kw.hr i.e.by 19.48% at full load condition when HHO produced at 3ampere supply. The decrease in BSFC is due to high energy content of the hydrogen present in the gas mixture, and also the combustion rate is high due to faster flame speed than gasoline assists to have more complete combustion.
4) At full load condition the concentration of HC has been reduced by 28.33% This decrease in percentage is due to oxygen index of HHO which yields better combustion, flame quenching distance of hydrogen present in gas is very less and also due to absence of carbon of in hydrogen fuel.
5) CO is reduced from 1.7% to 1.42% by volume when HHO produced at 3ampere supply. . One major reason for the reduction in CO level could be the availability of oxygen inside the cylinder which enters with hydrogen fuel due to which complete combustion occurs. Also the HHO-gasoline mixture burns faster and more completely than the pure gasoline.

Ammar A. Al-Rousan [2] 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 carburettor of a Honda G 200 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. Also, the volume of water needed in the cell is about one and half times the engine capacity.

Syed Yousufuddin. [3] At an equivalence ratio of 1.0 the percentage reduction in HC emission when the compression ratio was increased from 7:1 to 11:1 was around 22.4%.

1) At an equivalence ratio of 1.0 the percentage reduction in CO emission when the compression ratio was increased from 7:1 to 11:1 was around 32.58%.
2) As the compression ratio increased, the peak NOx emission occurred at lower equivalence ratios and therefore leaner mixtures.
3) At an equivalence ratio of 1.0 the percentage increase in NOx emission when the compression ratio was increased from 7:1 to 11:1 was around 27.8%.

Ismail M.M. Elsemary [4] “An experimental study was performed to explore the effect of hydrogen addition to gasoline fuel in a stationary spark ignition engine to bring out the optimum conditions for a better performance under different loads conditions. The results showed that the addition of hydrogen improves the brake thermal efficiency with the increase of hydrogen percentage up to percentage 31% for all tested loads. After that the thermal efficiency starts to decrease with the increase in hydrogen percentage more than 31% due to reduction in amount of air inside the cylinder. The same trends were noticed for HC and CO emissions values which also decrease with the increase in hydrogen percentage up to the same hydrogen fraction 31%. After that the amount of HC and CO missions starts to increase due to the high burning rate of hydrogen compared with gasoline and reduction in amount of air but not reach to their concentrations when using gasoline fuel alone. Comparing present results (with hydrogen percentages from 24% up to 49%) with experimental results (with hydrogen percentages from 5% up to 25%) was performed using percentage of enhancement for each hydrogen percentage compared with no hydrogen use. The comparing shows that there is a consistency in results trend for both experiments. Also the results of the two experiments together give a wide range of tested hydrogen percentages which help in exploring the engine performance when using hydrogen additions to gasoline fuel.

C. Hydrogen production by water electrolysis

When a water molecule passes through electrochemical process water molecules spilt in hydrogen and oxygen gases, this process is called water electrolysis. Electricity is used for the splitting the hydrogen and oxygen into their gaseous phase. The basic equation of water electrolysis is written in below equation.

$$2H_2O + Energy \rightarrow 2H_2 + O_2$$

For water electrolysis the energy is required as electrical energy and it is given from a DC power source. At room temperature the splitting of pure water is very small, approximately 10^{-7}. Moles/liter because pure water is the very poor conductor of electricity. Therefore, acid or base as an additive is used to improve the conductivity of water. In an alkaline water Electrolyser, KOH is mainly used with water. The solution splits into positive ions and negative ions and these ions readily conduct electricity in a water solution by flowing from one electrode to the other.

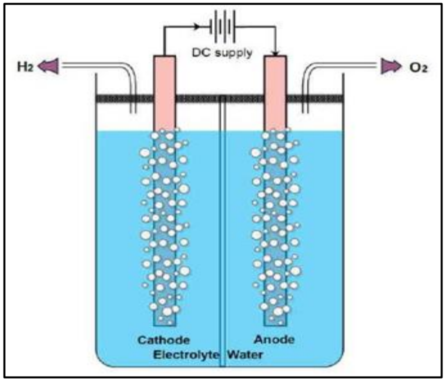

Fig. 1: Fundamental principle for electrolysis cell

The figure shows the fundamental principle for electrolysis cell. The general principle for all three technologies is the same. When a high voltage is applied to an electrochemical cell in presence of water, hydrogen and oxygen gas bubbles evolve at cathode (negative electrode) and anode (positive electrode) respectively.

Three approaches for the hydrogen evolution reaction (HER) and the oxygen evolution reaction (OER), the typical temperature range and the ions acting as the charge carrier through the diaphragm/membrane.

II. ENERGY CONSUMPTION

The energy required for decomposing one mole of water into hydrogen and oxygen corresponds to the enthalpy of formation of one mole of water. The minimum amount of the enthalpy of reaction that has to be applied as electrical energy is the free energy of reaction ΔG_{reac} (change in Gibbs free energy) defined in terms of enthalpy of reaction, ΔH_{reac}, Thermodynamic temperature, T and the Entropy of reaction, ΔS_{reac}, by below equation Eq.

$$\Delta H_{reac} = \Delta G_{reac} + T\Delta S_{reac}$$

Minimum energy required is given by Gibbs free energy relation deduce from Eq.

$$\Delta G_{reac} = \Delta H_{reac} - T\Delta S_{reac}$$

At Standard Temperature and Pressure the thermodynamic decomposition voltage of water in theoretically is 1.23V and the current efficiency is 100%. Therefore, the theoretical consumption of energy (E_{theo}) for producing 1 m^3 of H_2 is 2.94 kWh/m^3 H_2. However, for gas evolution the voltages needed is 1.65–1.7V. Therefore, in industries the voltage of about 1.8–2.6 V is used. Hence the practical energy consumption is nearly 1.5 to 2.2 times more than the theoretical energy consumption. Hence the actual efficiency is between 48% and 70%.

A. Water Electrolysis Thermodynamics

The thermodynamics of the water electrolysis reactions relate the voltages for the reactions at the anode and cathode of an electrolytic cell to the energy and entropy changes involved in breaking the chemical bonds in water and forming the chemical bonds in the diatomic hydrogen and oxygen gas products. These quantities are discussed for standard and non-standard conditions.

The standard potential for water electrolysis can be obtained from the standard Potentials for the two half reactions. For a basic solution shown in below Equations.

$$4OH^- \xrightarrow{\text{yields}} O_{2(g)} + 2H_2O_{(l)} + 4e^- \quad E^0 = -0.40 \text{ Volt}$$

$$4H_2O_{(l)} + 4e^- \xrightarrow{\text{yields}} 2H_{2(g)} + 4OH^-_{(aq)} \quad E^0 = -0.83 \text{ Volt}$$

$$2H_2O \xrightarrow{\text{yields}} 2H_{2(g)} + O_{2(g)} \quad E^0 = -1.23 \text{ Volt}$$

III. EXPERIMENTAL SETUP

Following components will be used in Experimental Setup:

- Engine test rig
- Eddy Current Dynamometer
- Fuel Measuring Unit
- Air Flow rate measuring Unit
- Temperature and pressure sensors
- HHO producing device
- Bubbler
- Battery (12 V)
- Flashback Arrestor
- Exhaust gas analyser

Fig. 2: Experimental Setup

A. Technical Specification of the Test Rig

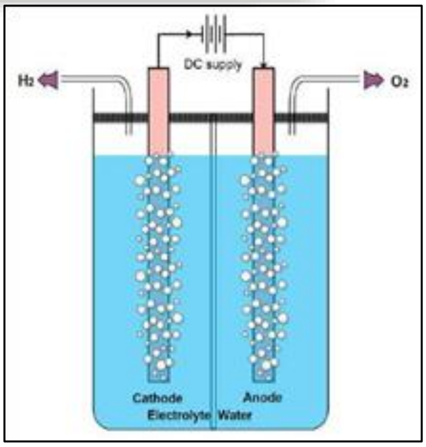

Fig. 3: Technical Specification of the Test Rig

Engine	
Make	Kirloskar
Model	AV1
Cooling	Water Cooled
Power	5HP @ 1500 RPM
Stroke	110mm
Bore	80mm
Volume	553 cc
Compression Ratio	9.51 : 1

Table 2: Technical Specification of the Test

IV. CALCULATION AND RESULTS

A. Fuel Consumption

$$\text{Fuel Consuption } (M_f) = \frac{\rho_{petrol} * \text{Amount of fuel consummed}}{\text{Time required}} \; ({}^{kg}/_{s})$$

Where,

Amount of fuel consume = 10ml

ρ_{petrol} = 740 Kg/m^3

B. Air Flow Rate

$$H_a = \frac{\rho_w * H_w}{\rho_a}$$

Where,

H_a = Height of air column in meter
H_w = Height of water column in meter
ρ_a = Density of air (1.2 kg/m^3)
ρ_w = Density of water (1.2 kg/m^3)

$$V_{air} = \sqrt{(2gH_a)}$$

Where,

V_{air} = velocity of air m/s
g = gravitational force m/s^2

$$Q = C_d * A * V_{air}$$

Where,

Q = volume flow rate m^3/s
C_d = co-efficient of discharge (0.65)
A = $\pi d^2/4$ (d = 20.5 mm)

$$M_a = \rho_a * Q$$

Where,

M_a = mass flow rate of air in kg/s

C. A: F ratio

$$A{:}F \; ratio = \frac{mass\ flow\ rate\ of\ fuel\ (M_a)}{mass\ flow\ rate\ of\ fuel\ (M_f)}$$

D. Equivalency Ratio (Φ)

$$\emptyset = \frac{Theoretical\ A{:}F\ ratio\ (15)}{Actual\ A{:}F\ ratio}$$

E. Brake Power (B.P)

$$B.P = \frac{2 * \pi * N * T}{60 * 1000} (KW)$$

Where,

N =Engine speed (rpm)
T = Engine Torque = W*R (N.m)
R = Arm length (350 mm)
W = load applied on engine (N)

F. Brake specific fuel consumption (BSFC)

$$\text{BSFC} = \frac{M_f}{B.P} \text{(kg/kWh)}$$

1) Load Vs Torque Graph

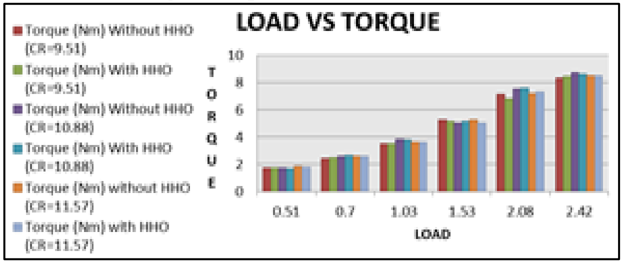

Fig. 4: Load Vs Torque Graph

2) Load vs BSFC Graph

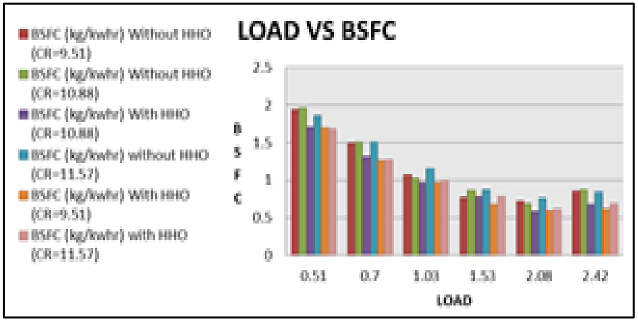

Fig. 5: Load vs BSFC Graph

3) Load vs Brake power

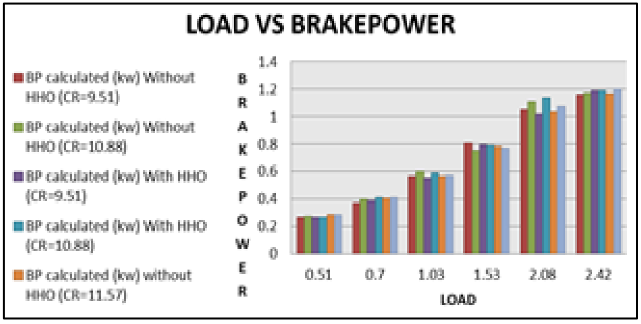

Fig. 6: Load vs brake power

4) Load vs CO %

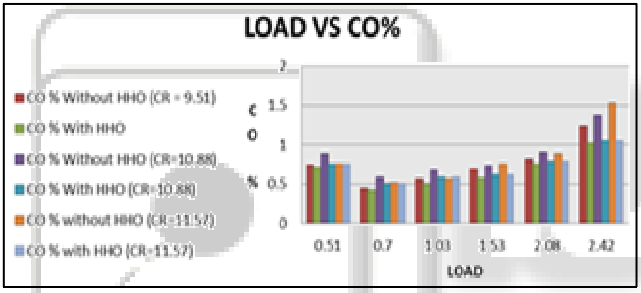

Fig. 7: Load vs Co%

5) Load vs CO_2%

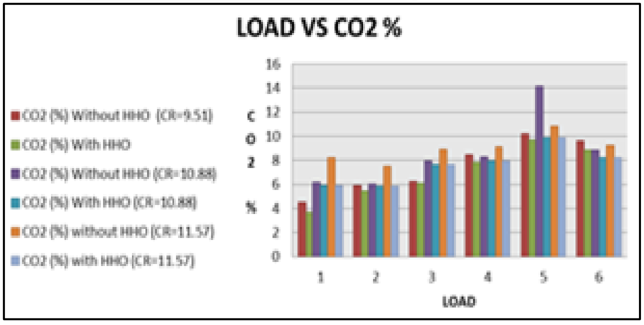

Fig. 8: Load vs Co_2%

6) Load vs HC

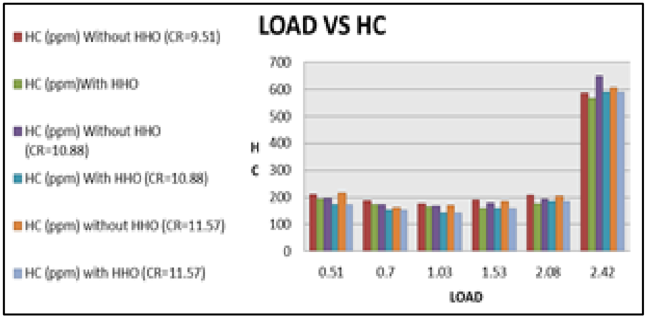

Fig. 9: Load vs HC

7) Load vs NOx

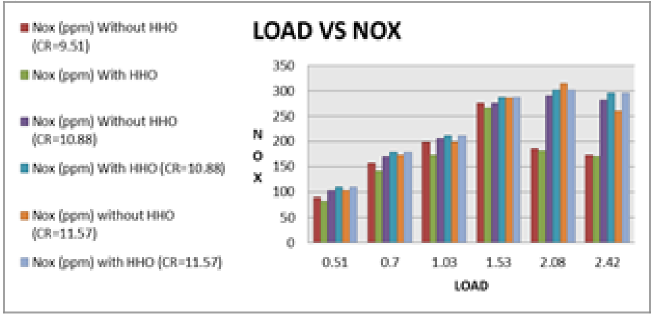

Fig. 10: Load vs NOx

V. CONCLUSION

- The engine thermal Brake power has been decrease when HHO gas has been introduced into the air/fuel mixture, consequently reducing fuel consumption.
- The concentration of CO_2, CO and HC gases has been reduced when HHO is introduced into the system at different compression ratio
- The concentration of NOx gas has been slightly increase when HHO is introduced into the system at different compression ratio.

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