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Investigating the Effect of Oxy-Hydrogen (HHO) gas and Gasoline Blend Addition on the Performance of Constant Speed Internal Combustion Engines

[#1]Shashikant Jadhav, [#2]Darshan Gabhane,[#3]Prof. S.S.Deshmukh

[1]shashijadhav91@gmail.com
[2]darsh9975@gmail.com

[#12]Dept. of Mechanical Engineering,
SRCOEM, Nagpur, Maharashtra, India.

[#3]Assistant Professor, Dept. of Mechanical Engineering,
SRCOEM, Nagpur, Maharashtra, India.

ABSTRACT

In recent times, using hydrogen or hydrogen enriched gas as a secondary fuel for spark ignition and compression ignition engine is one of the viable solution for improving brake thermal efficiency, reducing fuel consumption and emissions from internal combustion engines. 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. Here the oxygen enriched hydrogen-HHO gas was produced by the process of water electrolysis and device called HHO generator has been easily integrated with SI engine test rig. The experimental work is carried out on a 250cc single cylinder petrol engine under constant speed with varying load condition and amount of HHO gas aspirated into the combustion chamber along with intake air system at three different amperes i.e. 1 ampere, 2 ampere and 3 ampere with 12 volts DC supply. The result shows that the engine performance was best at 3 ampere, brake thermal efficiency of the engine increased by 3.72 %, total fuel consumption reduced by 18.87 %, brake specific fuel consumption reduced by 19.48%, moreover, the carbon monoxide (CO) and hydrocarbon (HC) has been reduced to about 16.47 % and 28.33 %. Also it was noticed that for all varying load gasoline produced higher exhaust temperature than gasoline +HHO gas mixture.

*Keywords :***Internal combustion engine, petrol Engine,electrolysis, oxygen Enriched Hydrogen-HHO, Emission.**

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I. INTRODUCTION

A. NEED OF ALTERNATIVE FUEL

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 to seek an alternative fuel that can be used in the engine. Without any dramatic change in engine design. Many researchers have found that hydrogen is clean and promising alternative fuel but use of hydrogen as an energy source in spark ignition engines involves four basic issues such as production, storage and transportation, safety aspects, utilization therefore produce hydrogen with electrolysis and used it in the form of HHO gas as an additive in internal combustion engines.

B. About HHO gas

It is a mixture of 2/3 of hydrogen and 1/3 of oxygen bonded together molecularly. It is generally produced by electrolysis of water. When electric current passed through water, it divides into hydrogen and oxygen. The hydrogen and oxygen rise from the liquid water as gas. This gas is called HHO Gas or Browns gas. After producing gas it is introduced into the air suction pipe and complete combustion occur.

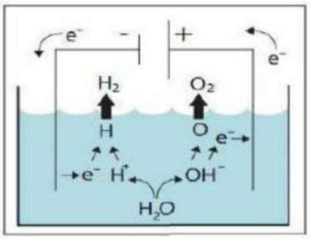


Fig.1Working principle of HHO Generator

HHO gas odourless, colourless and lighter than air. The HHO gas is highly flammable much more than gasoline. The Oxy-hydrogen explosion is so fast that it fills the combustion chamber at 3 times faster than gasoline explosion. At normal atom. Pressure auto ignition of Oxy-hydrogen occurs at about 570^0. Oxy-hydrogen gas has very high diffusivity. This ability to disperse in the air is considerably greater than gasoline. At normal temperature and pressure HHO gas can burn when it is between about 4% to 94% hydrogen by volume. Oxy-hydrogen is very low in density this result in a storage problem. When ignited, the gas converts to water vapours and release energy of about 241.38 KJ of energy (LHV) for every mole of H2 burned.

LITERATURE REVIEW

Most of the work has been done on the use of pure hydrogen as an additive, thought it gives better performance than any other alternative fuels available but, at same time which brings problem of storage, hydrogen supply infrastructure and wide flammability range makes it hazardous therefore viable solution to this problem is to produce it on board throughs water electrolysis and utilized it in the form of hydrogen-oxygen mixture and a very few research has been done on this concept therefore researches done in the recent years have been reviewed as follows.Leelakrishnan and Suriyan [14] investigated the effects of HHO gas enriched air on the performance of a single cylinder, four stroke, 5.4 kW SI petrol engine. Enriched air was supplied to the engine through a passage between the air filter and the carburettor. Results reported indicate 5% improvement in brake power, 7% improvement in thermal efficiency, 6% reduction in fuel consumption, 88% reduction in unburnt hydrocarbons (HC), 94% reduction in CO and 58% reduction in NOx. These values were reported at full load. However, no information was given on the rate of production of the HHO gas or whether there was variation in gas production during the test.Ali Can Yilmaz, el al. [8] produced HHO gas with different electrolytes KOH (aq.), NAOH (aq), NACL (aq) with various electrode design in a leak proof plexiglass reactor. Engine used was four cylinder, four stroke compression ignition engine. Dynamometer used has a torque range of 0-1700 Nm and speed range of 0-7500 rpm. performance parameter were measured by computer computer via a data logger software result showed that there was 19.1% increment in engine torque when HHO system was used compared to diesel operation where as 14% gain was achieved on specific fuel consumption using hydroxyl gas. Also about 13.5% reduction in CO emission and 5% reduction in HC but experiment showed that at low engine speed with constant HHO flow rate turned into disadvantage for torque ,CO,HC, and SFC this is because of long opening time of intake manifold at low speed which cause excessive volume occupation of HHO in cylinder which prevents correct air to be taken into combustion chamber due which volumetric efficiency decreases and decrease in volumetric efficiency influenced combustion efficiency which had adverse effect on performance parameter therefore hydroxy electronic control unit (HECU) it sense engine speed as soon as it lower and decrease HHO flow rate by decreasing voltage and current automatically and compensate disadvantage under lower engine speed.

Ammar A. Al-Rousan [9] conducted performance test on the single cylinder spark ignition air cools 197cc engine and HHO production system was designed, constructed, integrated with a gasoline engine. i.e. the output of fuel cell connected to the intake manifold of the gasoline engine and performance test was performed before and after attaching fuel cell with constant load and variable speed (from 1000 to 2500 rpm) and result shows that brake thermal efficiency increase about 3% for cell B and 8% foe cell C and 20 to 30% reduction in fuel consumption and exhaust temperature. And research showed that use of HHO in petrol engine enhances combustion and optimum surface area needed to generate enough amount of HHO is about twenty times that of piston surface area also, the volume of water needed is about one and half times engine capacity.

Musmar and Al-Rousan [10] conducted research on single cylinder 197cc gasoline engine to see effect of HHO gas on combustion emission. The emission test have been done with constant load and varying engine speed (1000-2300 rpm). Graph between CO Vs. engine speed depicts that with addition of HHO gas there is 20% reduction in CO emission because of better combustion efficiency and better efficiency is due to the hydrogen and oxygen atoms interacts directly without any ignition propagation delays and also due to HHOs flame speed is much higher than ordinary fuel. Also reduction in HC concentration seen. This reduction in HC emission increases with engine speed and at 2300 rpm, reduction in HC emission to about 40% this tells that HC emission is highly affected by the engine speed. It was also noticed that exhaust gas temperature reduces when HHO gas utilized with gasoline and exhaust gas temperature is directly related to NOx concentration this leads to lower NOx emission. This was a result on no control on electric current fed to HHO generator. No information is given regarding the performance of the HHO generator used.

A.M.Falhat, et al. [11] carried out experimentation on 197 cc SI engine with gasoline and HHO gas as secondary fuel and compared with pure gasoline fuelled engine. In this HHO flow meter was employed with HHO production system to add HHO gas at 1,1.5 and 2 lpm and engine speed was varied from 1350 to 2250 rpm and it was noticed that gasoline produced less torque and power compared with gasoline+HHO mixture and it was increases with increase in flow rate of HHO gas, maximum increase of torque and brake power about 12.6% further it was noticed that specific fuel consumption decreases about 16.9% at 1350 rpm while minimum reduction was about 2.9% at 1750 rpm when HHO flow rate was 2 lpm. The graph between thermal efficiency Vs. speed depicts that for all speed range studied gasoline produced less thermal efficiency compared with gasoline +HHO mixture and also noticed that the maximum gain is about 23% at 1350 rpm and minimum was about 14% at 2250 rpm. And it was seen that the concentration of CO and NOx is decreases with increase of flow rate of HHO gas.

This paper investigates the engine performance from partially including hydrogen gas also known as browns gas or HHO gas into the combustion process of a conventional spark-ignition engine and no work has been reported in literature on constant speed four stroke gasoline engine.

EXPERIMENTAL SETUP AND PROCEDURE

Figure 1 shows the schematic diagram of experimental system. The experiment was conducted on 256cc S.I. engine using carburettor system. The engine was coupled to electrical dynamometer in order to load the engine. For loading engine four electrical heaters each of 350 watts available in the system. The gasoline fuel consumption was measured by fuel burette and stop watch and Air box method was used for measured consumption of air. HHO production system was integrated with engine setup. HHO gas generated by dry cell using 12 volt external DC supply. The generated HHO is then passed through fire trap container before it is introduced to the engine via the air inlet manifold. The current controller and PWM employed to control the current fed to the electrolytic cell. A K-type thermocouple was installed to measure the exhaust gas temperature. For the analysis of emission exhaust gas analyser connected to the exhaust pipe. It gives emission quantity present in gas like CO and HC.

The engine used in experimentation is constant speed air cooled single cylinder, 4-stroke petrol engine.

The specification of engine as follows.

Make of the Engine	Crompton Greaves MK
Rated Power	2.2 Kw @ 3000 RPM
Bore/stroke (mm)	70mm/66.7 mm
Compression Ratio	11:1
Swept volume (cc)	256 cc

improve efficiency.

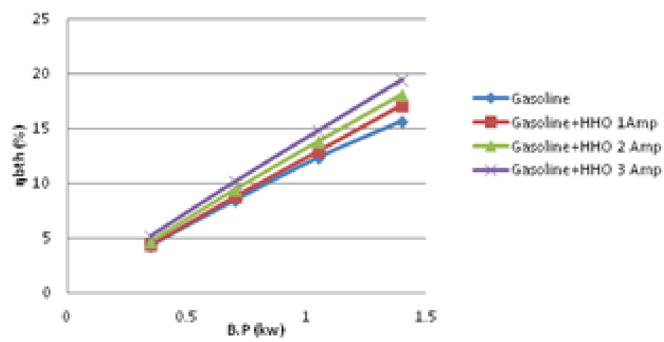


Fig 3.1 Variation of brake thermal efficiency with B.P.

3.2 Effect of HHO on Brake Specific Fuel Consumption.

Brake specific fuel consumption can be defined as fuel energy utilized to produce unit brake power. Fig 5.2 shows the variation of brake specific fuel consumption with the brake power. At 100% rated load of the test engine, the BSFC decreases from 0.4782 Kg/kw.hr to 0.438 Kg/kw.hr at 1 ampere, from 0.4782 Kg/kw.hr to 0.414 Kg/kw.hr at 2 ampere and from 0.4782 Kg/kw.hr to 0.385 Kg/kw.hr at 3 ampere. 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.

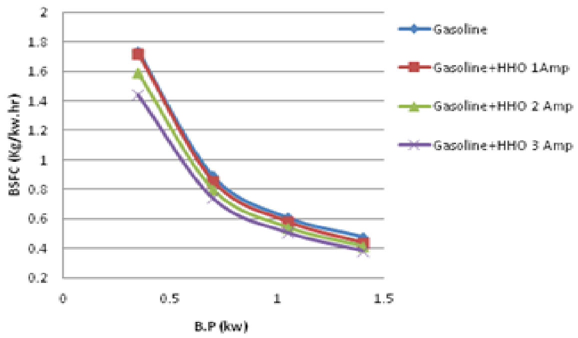


Fig 3.2 Variation of Brake Specific Fuel Consumption with B.P.

3.3 Effect of HHO on Total Fuel Consumption.

Fig.3.3 illustrates the variation of the total mass flow rate of fuel with the percentage of HHO mixture. As expected, the induction of HHO reduces the total fuel consumption rate of the engine under all applied load conditions. At 1 ampere formed HHO mixture the total fuel consumption decreased by 7.8261 % at full load condition .At 2 ampere current, the decrease in total fuel consumption is found to be 14.05% at full load condition, at 3 ampere, the reduction in total fuel consumption rate reaches its highest value as 18.87 %. 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.

Fig 3.3 Variation of Total fuel consumption with brake power.

3.4 Effect of HHO on Air Fuel Ratio

Figure 3.4 depicts the variation of air–fuel ratio with HHO percentage. The figure shows that the air–fuel ratio increases with increasing HHO at no load condition. These are due to the fact that the inducted mixture contains oxygen as well. This increase in air–fuel ratio improves the combustion resulting lower fuel consumption and better efficiency as described earlier. The increases in air–fuel ratio at the various currents were from 10.63 to 10.91, from 10.63 to 11.13 and 10.63 to 11.57 at 1amps, 2amps and 3 amps respectively at full load condition.

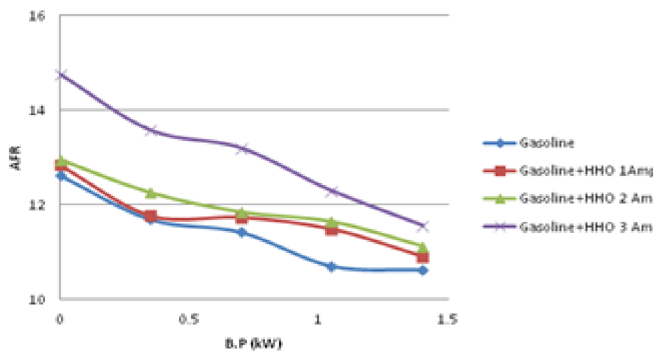


Fig 3.4 Variation of Air fuel ratio with brake power

3.5 Effect of HHO on Exhaust Temperature

Figure 3.5 shows the effect of HHO gas on exhaust temperature. It is noticed that for all loading range studied, gasoline produced higher manifold temperature compared with gasoline- HHO mixture. This can be due to the act that when hydrogen burns it forms H2O which absorbs part of the combustion chamber heat for its evaporation. Further, it is noticed that the exhaust temperature increases with engine load. This is because higher the engine load and speed less will be the time available for the products to lose its heat to the surrounding.

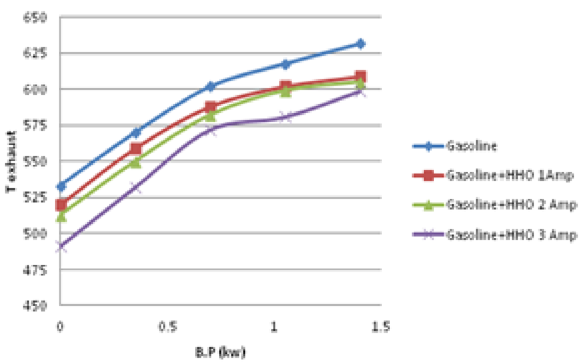


Fig 3.5 Variation of Exhaust temperature with brake power

3.6 Effect of HHO on CO Emission

It is noticed that the addition of small quantities of HHO gas to the primary gasoline significantly reduced CO exhaust emissions. 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. Thus, CO emission at high speed and lean conditions is effectively reduced after hydrogen addition. Optimum reduction in CO is achieved is from 1.7 % to 1.42 % at 3ampere HHO production at full load condition.

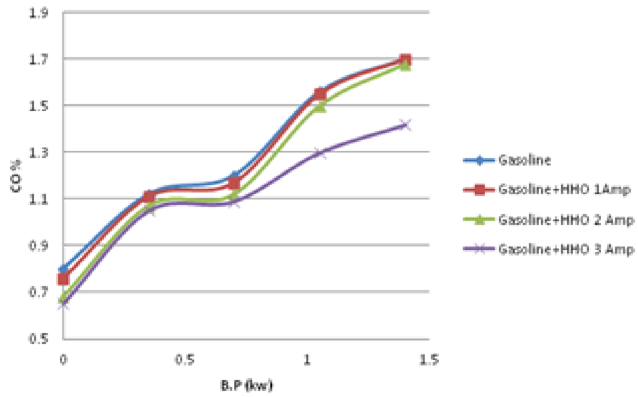


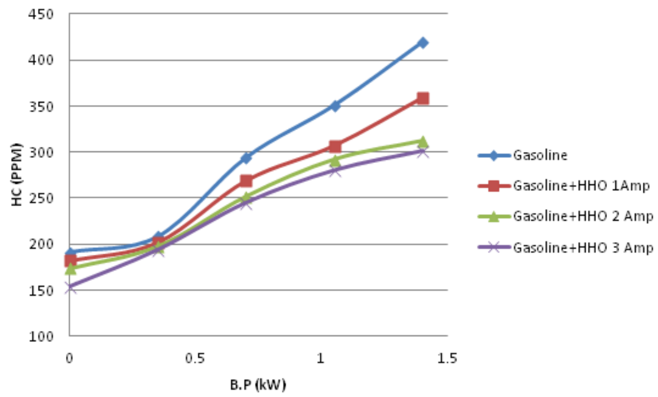
Fig 3.6 Variation of CO% with brake power

3.7 Effect of HHO on CO Emission

Figure 3.7 depicts the variation of hydrocarbon (HC) with HHO addition under different load condition. When HHO

Fig 3.7 Variation of HC with brake power

gas mixture at 3 ampere is introduced into cylinder, resulting in 420 ppm at 100% rated load of the engine, at the same time HC emission of pure gasoline is 301 ppm, by a decrease of 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.

IV. CONCLUSIONS

The main results obtained from the present study are as follow.

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.

6) It is noticed that gasoline produced higher manifold temperature compared with gasoline-HHO mixture. This can be due to the act that when hydrogen burns it forms H2O which absorbs part of the combustion chamber heat for its evaporation. Further, it is noticed that the exhaust temperature increases with engine load. This is because higher the engine load and speed less will be the time available for the products to lose its heat to the surrounding.

V. FUTURE WORK

This experiment can be taken to a higher level of research by finding appropriate ratio of HHO to gasoline required to get optimum mileage as well as desired emission level.Another area of improvement can be develop ways in which energy released during this process of hydrogen generation through electrolysis could be increased.Instead of injecting HHO gas into intake manifold. if it is injecting directly to combustion chamber through nozzle then there is a possibility to get better results and also better for safety because there no chances of back fire.

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