A Review on Effect of Oxy-Hydrogen (HHO) Gas Addition on the Performance of Internal Combustion Engines

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Abstract— Research and development work on hydrogen technology has been done since from 18 centuries. Innovative ideas have been put forward; recently, using hydrogen or hydrogen-rich gas as a secondary fuel for engines is one of the solutions for improving brake thermal efficiency, reducing fuel consumption and pollution emissions from internal combustion engines. Theoretical studies have been performed on HHO fueled internal combustion engines. In an HHO production system HHO gas is produced by electrolysis of water, which is a mixture of 2/3 of hydrogen and 1/3 of oxygen bonded together molecularly. This article gives a review of the effect of HHO gas addition on engine performance and emission characteristics.

Keywords: Internal combustion engines (IC Engine), HHO, Hydrogen, Electrolysis

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.

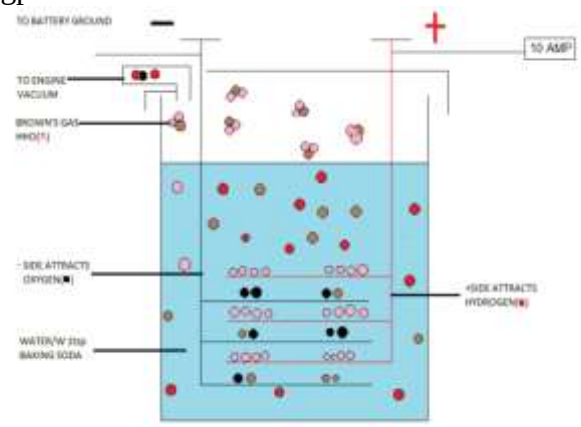

Fig. 1: Working Principle of HHO Generator

HHO gas odorless, colorless 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 vapors and release energy of about 241.38 KJ of energy (LHV) for every mole of H2 burned.

II. 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 throught 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.

S.Bari and M.Esmaeil (9) were performed experimentation on four cylinder direct injection diesel engine the experiment were carried out under constant speed of 1500 rpm with three different power level of 19 Kw, 22Kw and 28 Kw applied. Under each load condition flow rate of diesel and other parameter were recorded without HHO then small amount of HHO mixture was introduced to the engine and measured the performance parameter at each load condition then flow rate of HHO gas was increases and required data were collected. The result showed that with introduction of HHO gas at different percentage into diesel engine ,the brake thermal efficiency increased by 2.6% at 19Kw, 2.9% at 22 Kw and 1.6% at 28 Kw. The brake

specific fuel comsuption of engine reduced by 7.3% at 19 Kw, 8.1% at 22kw and 4.8% at 28Kw. It was also noticed that adding HHO beyond 5% does not have significant effect on engine performance. The emissions HC, CO and CO2 were found to be reduced while NOx increases due to higher temperature achieved during combustion process.

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% increament 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 turnrd 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 (5) conducted performance test on the single cylinder spark ignition air cooles 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 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 varing engine speed (1000-2300 rpm). Graph between CO Vs engine speed depicts that wuth 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 intracts 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 exhast 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.(1) carried out experimentation on 197 cc SI engine with gasoline and HHO gas as secondary fuel and compared with pure gasoline fueled 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.

In more recent work, Tuan Le Anh, et al.(3) carried out experimentation study on 97cc SI engine equipped with two injection system (HHO gas and additional air) on the intake manifold. Also, test rig was integrated with electronic HHO control (EHC) unit which control the flow of HHO into intake manifold. The experimental study were carried out at three position of throttle 30%,50% and 70% with different range of speed for test lamda matrix. The speed controlled by level of water in brake and HHO were controlled by EHC in order to obtained the ratio of HHO gas in the mixture about 1.95% by mass over all of considered throttled position the formula for calculating lamda of petrol and HHO mixture is as follows.

$$\lambda = \frac{(dm/dt)_{Air}}{(dm/dt)_{Gasoline}.(A/F)_{Gasoline} + (dm/dt)_{HHO}.(A/F)_{HHO}}$$

For each throttle position and engine speed, the engine was fueled with three mixture, gasoline with intake air (case 1),gasoline+intake air+HHO (case 2) and gasoline+intake air+HHO+additional air (case 3). The result shows that engine power increased by 2.35% and 2.78% when adding only HHO gas and mixture of HHO gas+additional air respectively whereas the changes in exhast gas emission in case 2 and case 3 shows same trend in NOx and HC emission however CO and CO2 showed opposite trends in case 2 and case 3. From this it has been concluded that effect of HHO gas adittion at light load and lean condition is more acceptable whereas the addition of only HHO gas makes mixture rich and which brings adverse effect to CO however HHO+additional air can makes mixture leaner and lower the CO emission. Auther also developed one-dimentional model of engine in AVL boost software to estimate the combustion characteristics of the engine fuelled with HHO gas. The mass fraction of two gases were considered as 0.889 for oxygen and 0.111 for hydrogen and fractal combustion model was choosen for analysis and the difference between simulated and

experimental data of 2.88% which ensures accuracy and result were validated.

III. CONCLUSION

A very less study has been done on HHO as an alternative fuel. HHO generation rate and their exact properties with values are not explored much. One of the main advantage of HHO system is that HHO can be controlled with the help of voltage and current regulation and can be easily integrated with any engine test rig. This review gives the trend of development and experimentation performed on the concept. The use of HHO gas as a supplement fuel help in increase in mileage, increase brake power,reducing exhaust emission. Due to its properties such as wide flammability range, high flame speed and short quenching distance of hydroxyl yields fuel to be combusted completely under high and lower speed conditions.

IV. 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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