ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 6, Issue 4, pp: (473-478), Month: October - December 2018, Available at: www.researchpublish.com

# Application of Hydrogen as a Supplementary Fuel in 4-Stroke Internal Combustion Gasoline Engine

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***Abstract:*** **The ever increasing cost of conventional fossil fuels and their associated environmental impact have become major concerns worldwide. At global level, scientists warn that the combustion of fossil fuels is significantly changing the world's climate system. In order to conserve the petroleum fuels for future and to eliminate the environmental problems there is need of alternative fuel. In order to overcome the draw backs of the fossil fuels it is the time to completely or partially replace this fuel. So an innovative idea to overcome these problems is the HHO gas. HHO gas is also known as brown gas produced from splitting water into hydrogen and oxygen from electrolysis and allowing the gas to stay in a premixed state for use on demand without the need of storage. In this paper, we have analysed the scope of hydrogen as a supplementary fuel, in 4-Stroke internal combustion gasoline engine. A hydrogen generation system for producing hydrogen and injecting the hydrogen as a fuel supplement into the air intake of carburetor. Hydrogen and oxygen is produced with a fuel cell at low temperature and pressure from water in a tank. The device is powered by vehicle battery. The system is modified such that power is permitted to electrolysis cell only when ignition switch is turned ON. The performance and emission characteristics of a conventional single cylinder spark ignition (SI) engine operated on gasoline and gasoline with hydrogen has been reported.**

***Keywords:*** **IC Engine, Electrolysis, HHO gas, Exhaust emission.**

## I. INTRODUCTION

Hydrogen, as a fuel, presents an excellent substitute to fossil fuels due to current environmental concerns and a bid to reduce oil dependency. Hydrogen can be produced from a range of sources and its chemical reaction in air does not produce any greenhouse gas emissions. Compared to gasoline, hydrogen has more energy per unit mass, a higher flame speed, wider flammability limits and a lower minimum ignition energy and these unique properties make hydrogen an attractive alternative in the transportation sector. The hydrogen and fuel cell power based technologies that are rapidly emerging can now be exploited to initiate a new era of propulsion systems for small commuter vehicles. These technologies can also be developed for the future replacement of fossil fuel engines in vehicles. Hydrogen is expected to provide the fueling source on the medium term and for use in common applications. Fuel cells could become the main power source for small general vehicles or could replace several internal subsystems on transport vehicles. Hydrogen based fuel cell automotive system designs are expected to facilitate the gasoline fuel system in automobile applications in the near-term. The replacement of combustion engines with hydrogen fuel cells powered vehicles can guarantee a massive reduction of pollution, (since the only emission produced by a fuel cell is water) and noise pollution. Nevertheless, the available fuel cell technologies need substantial improvements to meet safe operational requirements in terms of efficiency, reliability, performance, mass/volume, cost and lifetime at any road conditions and under high and low ambient temperatures on the ground. Mohamed M. EL-Kassaby et. al [1] were performed experimentation and concluded that the HHO gas maximum productivity of the cell was 18 L/h when using 2 neutrals plates with 1 mm distance and 6 g/L of KOH. The results also showed 10% increment in the gasoline engine thermal efficiency, 34% reduction in fuel consumption, 18% reduction in CO, 14% reduction in HC and 15% reduction in NOx. Shivaprasad et. al [2] have experimented on a single cylinder SI gasoline engine while injecting H2 in the intake manifold in volumetric fractions (Vf) of the intake air between 5% and 25%. The results reported a continuous increase in Bmep and thermal efficiency, and a decrease in both HC and CO emissions, with an increase in H2 fraction. Unfavorably, a corresponding increase in NOx was reported with the rise in H2%.

Bari S. et. al [3] were performed experimentation on four cylinder direct injection diesel engin e 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 consumption of engine reduced by 7.3% at 19 Kw, 8.1% at 22kw and 4.8% at 28 Kw. 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. Ammar A. [4] conducted performance test on the single cylinder spark ignition air cooled 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% for 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. Leelakrishnan E. et. al [5] 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 carburetor. 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.

Desai Fenil et. al [6] conducted research on performance and emission assesement of hyro-oxy gas in four stroke spark ignition engine. Elecronic control unit was designed and manufactured to decrease HHO flow rate by decreasing voltage and current. In the experimental setup analysis of the performance of internal combustion engine was analysed where a blend of HHO gas was provided with the conventional fuel like petrol or diesel. With the addition of HHO gas, Specific fuel consumption decreased by 22%at 1960 RPM, whereas Sox and NOx emissions were reduced by 15% and more than 50% CO2 reduction. Amruthraj M. et.al [7] controlled emission in internal comustion engines to a greater extent. A hydrolyse kit was designed which reduced the hydrocarbons emissions by 99.25% and carbon monoxide emissions by 98.688%.

## II. HHO KIT WORKING

HHO gas (hydroxyl gas) 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. The catalyst used to produce oxy hydrogen gas (HHO) is Potassium hydroxide (KOH). The electrical supply used for process is connected to the vehicle's battery. Hydrogen will appear at the cathode and oxygen will appear at the anode material i.e. reduction at cathode and oxidation at anode takes place. The amount of hydrogen generated is twice the number of moles of oxygen and both are proportional to total electrical charge conducted by electrolyte solution. The generated HHO gas is then supplied to the bubbler tank which will give the indication of generation of HHO gas. Then the proportional amount of HHO gas is supplied to intake manifold of the engine. Whenever the vehicle is started, current is passed through electrolysis circuit and HHO gas starts producing.

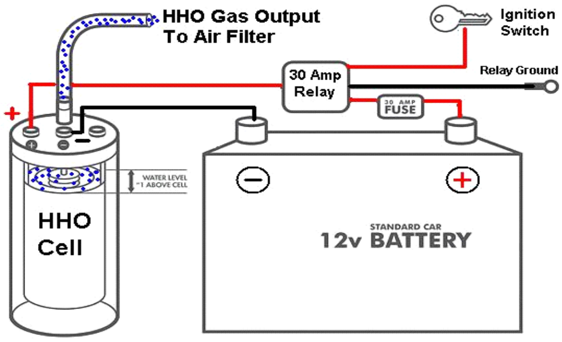



**Figure 1: Working principal of HHO Kit**

## III. WORKING PRINCIPLE

The hydrogen generated at cathode is fed to the inlet manifold that is in air hose pipe of the Carburetor, then this gas mix with the coming air from the air filter when the vacuum is created by the piston movement from TDC to BDC. As the hydrogen or HO gas mixed with air then it goes to engine cylinder with gasoline during suction stroke of the engine. At the end of compression stroke the spark is generated from the cold rated spark plug the combustion of gasoline and HO gas occurs. HHO itself contains 1/3 oxygen by volume and 2/3 hydrogen (which has an octane rating of 130).The hydrogen explosion is so fast that it fills the combustion cylinder at least 3 times faster than the gasoline explosion and subsequent ignites the gasoline from all directions hence more power is generated.

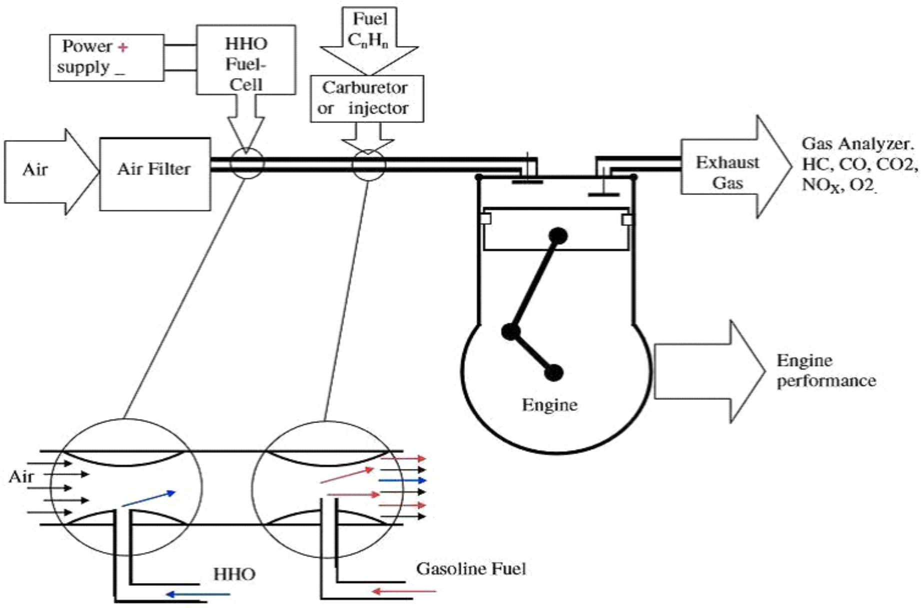



**Figure 2: Schematic illustration of HHO system installed on IC engine**

## IV. PERFORMANCE ANALYSIS

### *A. Mileage Test:*

In this paper we have conducted mileage test on Bajaj Discover 100 DTS-i to ensure the advantage gained on using this innovative technique. Mileage is nothing but the fuel economy of any automobile. It is the total distance travelled by the automobile for specified quantity of fuel. The hydrogen explosion is so fast that it fills the combustion cylinder at least 3 times faster than the gasoline explosion and subsequently ignites the gasoline from all directions. Hence more power is generated consequently the mileage of bike is also increased. The burn speed of hydrogen is 0.098 to 0.197 ft./min (3 to 6 cm/min) as compared with gasoline which is 0.00656 to 0.0295 ft./min (0.2 to 0.9 cm/min). From fig. it is cleared that distance covered by vehicle with the addition of HHO gas as compared to pure gasoline is more which proves the effective usefulness of HHO gas with gasoline.

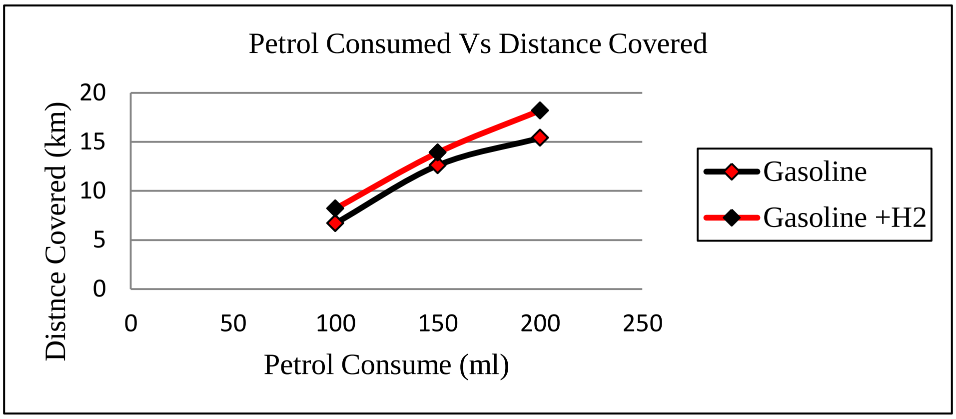
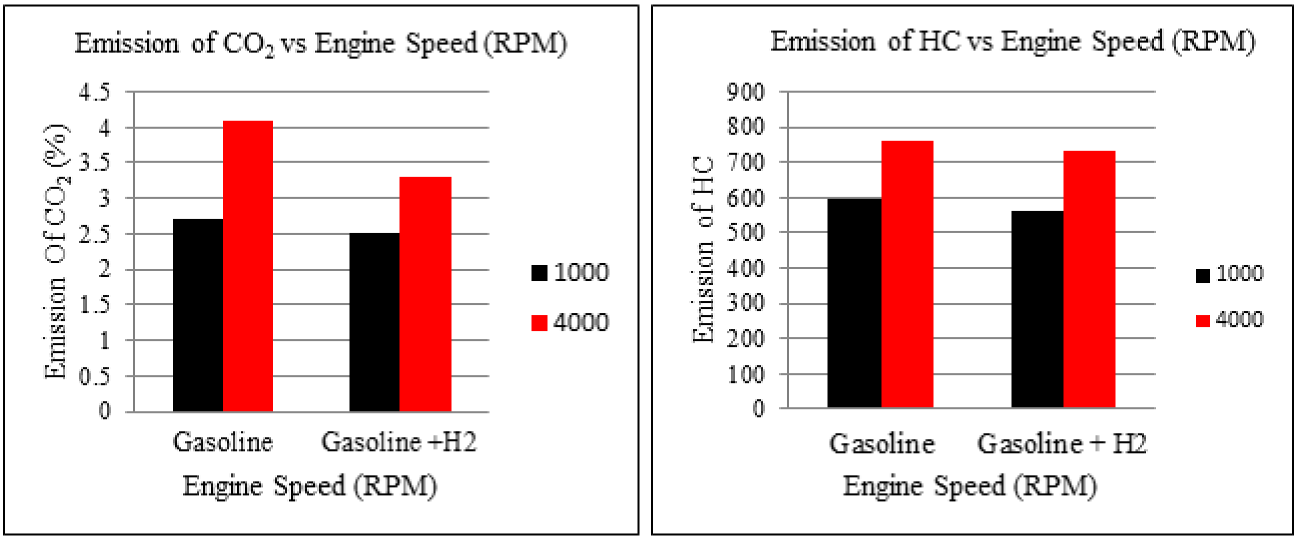



**Figure 3: Graph of petrol consumed vs. distance covered**

### *B. Emission Test:*

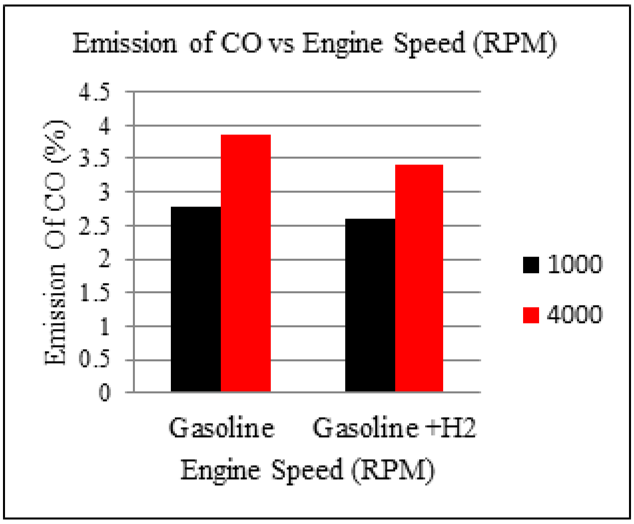
Due to the combustion of fuels in the vehicle some gases (exhaust gases) are produced such as hydrocarbons (HC), carbon dioxide ($CO_2$), carbon monoxide (CO), nitrogen oxides (NOx), etc. This is called emission of gases in automobile. We know that these gases are one of the reasons for global warming. So our research aim is to reduce these harmful emission with the help this new technique. The emission test is carried out by Auto Exhaust Multigas Analyser Model no. NPM-NGA-2.



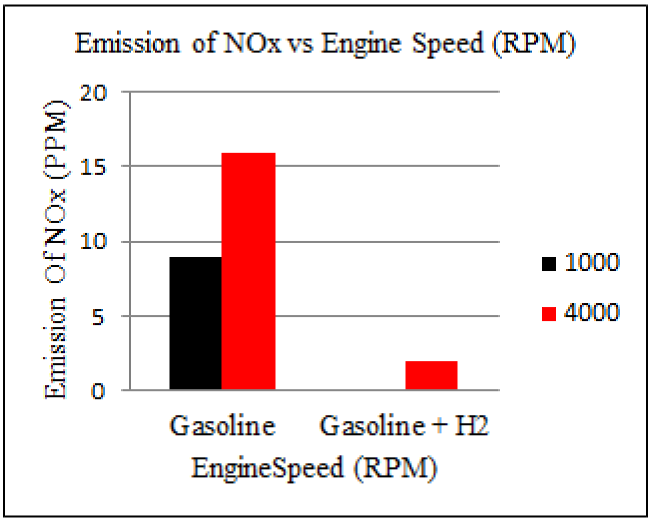

**(a)** **(b)**

**Figure 4: (a) Emission of CO2 vs. engine speed in RPM. (b) Emission of HC vs. engine speed in RPM.**

Emission gases are generated in an engine when it is operated with a fuel-rich equivalence ratio. These emissions can be reduced by operating the engines at leaner ratios. HHO gas fuelled engine can be operated at leaner ratios, thus resulting in reduced level of $CO_2$ & HC emissions. Figure 4 show the reduction in $CO_2$ & HC emission level for gasoline with HHO gas fuel compared to that of gasoline fuel. This is because of the operation of the engine at lean ratios. Short quenching distance and wide flammability range of hydrogen yield engine to expel less HC emission which is an indication of combustion stability. Carbon monoxide is a colourless poisonous gas. Small amount of CO concentration when inhaled slows physical and mental activities. Carbon monoxide is found only in engine exhaust. It is a product of incomplete combustion due to insufficient amount of air in the air fuel mixture or insufficient time in the cycle for completion of combustion. As engine lubrication oil film sticks onto the cylinder wall and burn with the air-hydrogen mixture, it can account for these of carbon emission, absence of carbon in hydroxyl gas is a major reason for CO reduction. NOX are formed inside the combustion chamber due to presence of excess of oxygen and high combustion temperature that fevers for oxidation reaction. Figure 5 show the reduction in CO & NOx emission level for gasoline with HHO gas fuel compared to that of gasoline fuel.




(a)




(b)

**Figure 5: (a) Emission of CO vs. engine speed in RPM. (b) Emission of NOx vs. engine speed in RPM.**

## V. CONCLUSION

Experimental investigation has been carried out in single cylinder IC engine with the addition this technique and conclusions were drawn. Hydrogen is a very clean fuel which hardly leaves any deposits on engine parts. This technique improves fuel efficiency of a normal bike engine and brought down the fuel consumption by almost 25%. HHO technologies are very promising and can serve as an important foundation in increasing the mileage of all vehicles by saving fuel and saving environment. Also reduces engine noise and vibration. The concentration of HC, CO, $CO_2$ and NOx gases has been reduced to almost 12%, 13%, 24% and 15% respectively on average when HHO is introduced into the system. It is recommended for the future work to study the effect of both compression ratio and ignition advance on the engine performance and emissions with introducing HHO gas into the gasoline engine.

## VI. AKNOWLEDGEMENT

The authors would like to be obliged to Sipna College of Engineering and Technology, Amravati (M.S), India for providing laboratory facilities and all experimentation related equipment’s for research work.

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