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Performance Analysis of a Four Stroke Multi-cylinder Spark Ignition Engine Powered by a Hydroxy Gas Booster

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Abstract—*In the present study an attempt has been made for using alternative fuels in four stroke multi-cylinder spark ignition engine. This work investigates the performance of a SI engine fueled with blend of petrol and Hydroxy Gas (HHO) and compares its results with petrol. HHO gas is generated with the help of Electrolysis technique using electrolytes (KOH and NaOH) in a leak proof Hydroxy generator which requires very little power to operate. A HHO generating electrolyzer with bubbler is induced in the engine set-up and HHO gas is supplied to engine through its intake manifold. This generated HHO gas is being used with the primary fuel i.e. petrol, in the selected engine without any modification. The performance measures investigated are brake power, specific fuel consumption, brake thermal efficiency and exhaust gas temperature. This study has been performed by varying load on engine from 0% to 100% and analyzing its effect on the selected performance parameters. Moreover the results have shown that HHO blended petrol lead to increase in brake power by an average of 11.5%, reduce specific fuel consumption by an average of 6.35%, increase in brake thermal efficiency by an average of 10.26% and reduce exhaust gas temperature by an average of 3.9% and hence subsequently showing that it may be useful in internal combustion (IC) engines to combat global warming effects. There is a significant increase in demand of fossil fuels which is leading to irreversible climatic changes. Due to burning of fossil fuels rejection of harmful exhaust gases takes place, leading to greenhouse effect and further to irreversible global warming. Therefore in order to conserve conventional energy resources there is an utmost requirement of using alternative fuels. Consequently HHO may be proved as emerging alternate energy source for IC engines in order to mitigate above problems.*

1. INTRODUCTION

The requirement of fuel is increasing day by day due to increase in population and vehicles in different modes of transport. Fossil fuels have the maximum share in all the fuels available to drive the vehicle engines. As fossil fuels are available in limited amount it is very necessary to use them wisely. Also the combustion of these fuels give out many harmful greenhouse gases in large amounts which are controlled at some extents. The green house gases contribute to irreversible global warming and climate change.

In today's world with latest technologies, fossil fuel alternatives, like bio-fuels and hydrogen can be used to reduce the greenhouse gas emission. Mixing hydrogen with fossil fuels helps in increasing the calorific power which in-turn reduces greenhouse gas emission.

Adding hydrogen to fossil fuel reduces emissions as well as fuel consumption. It also helps in increasing the power of the engine.

In the present study focus has given to check the feasibility of using petrol and hydroxy gas blend in order to enhance the performance of a multi cylinder 4 stroke SI engine. The objectives considered for carrying this study are as follow:

1. To check for enhanced brake power and thermal efficiency.
2. To check for reducing specific fuel consumption and exhaust gas temperature.

2. LITERATURE REVIEW

Engines which use hydrogen as a primary fuel are not made at par with conventional engine specifications which run purely on fossil fuels. The engines using hydrogen are expensive to manufacture as compared to conventional engines. Therefore using pure hydrogen is not economically balanced, whereas hydrogen can be used along with other available fossil fuels, and this mixture can be used in a conventional engine. This will maintain the low cost as well as solve the purpose of reducing emissions and increasing efficiency.

[4] & [5] reported that by using hydroxy gas with different fossil fuels, it had led to enhance engine efficiency, proved emission reduction, remove deposits of carbon, higher torque, more power and better economy of fuel.

Santilli [10], in his study, presented for the very first time the generation of a hydrogen and oxygen mixture known as HHO

gas produced with the help of an electrolyzer. He had created this combustible and gaseous HHO from distilled water at atmospheric pressure and temperature. With the support of experimental data he had confirmed the existence of a new form of water (i.e. HHO) with magnecular and molecular bond.

Al-Rousan [1], in his research used HHO gas in a 197 cc single cylinder gasoline engine. He suggested that for generation of HHO, Fuel cell must be design in such a way that surface area of an electrolyte used 20 times of piston surface area as well as the quantity of water required should be 1.5 times the capacity of engine. His study represented that by integrating HHO with engine fuel consumption was significantly reduced by 20 -30% as well as exhaust gas temperature was also reduced. The author had emphasized for adding sodium bicarbonate gradually into fuel cell in order to ensure control heat generation. The author also had represented that by adding HHO gas with gasoline there was an increase in octane rating of fuel and hence it led to efficient combustion of the fuel.

Musmar and Al-Rousan [8] also used HHO gas in a 197cc single cylinder SI engine. They performed their study by varying speed in the range of 1000 rpm to 2300 rpm at a constant load. Their analysis presented that by using a mixture of air, gasoline and HHO in a single cylinder gasoline engine had led to reduce NO and NO_X emission. They also reported about 20% decrease in CO emission from engine exhaust gas.

Bhardwaj et al. [2] performed their study by adding brown gas in a petrol engine and then evaluated the major performance measures. They had done their analysis by varying load on engine from 5 kg to 20 kg. They reported significant increase in power, indicated thermal efficiency and air fuel ratio. They also reported a significant decrease in HC, CO_2 and CO emissions. Nevertheless they did not report about the speed at which this study was carried out by varying load on engine.

Yilmaz et al. [12] produced hydroxy gas by the electrolysis of water in the presence of different electrolytes. They used it as a secondary fuel along with diesel in a four stroke CI engine. Their analysis had shown that adding HHO below 1750 rpm speed led to lower torque output, higher specific fuel consumption, HC and CO emissions which eventually proved as a disadvantageous for the engine performance. The authors had reported that supplying HHO with diesel was only beneficial when engine speed is higher than 1750 rpm which would have led to higher engine output torque, lower specific fuel consumption, CO and HC emissions.

Levie [6] had discussed a brief review about electrolysis of water.

Yamin and Hamdan [11] had studied the performance of hydrogen on a 4 stroke gasoline engine with the help of a self designed fuel regulator. They had reported that there was an improvement in specific fuel consumption and thermal efficiency was unchanged when engine was fueled with hydrogen. Nevertheless it was investigated that volumetric efficiency and brake power had reduced significantly when using hydrogen.

Chatterjee et al. [3] had also supported for using hydrogen as a feasible option in IC engines. They had represented a comprehensive overview about the basics of hydrogen combustion, hydrogen properties as an IC engine fuel and effect of mixing hydrogen with fuel on the engine's performance measures. They had supported that higher octane rating and low flammability limit of hydrogen led to higher thermal efficiency and lower exhaust gas emissions.

Morais et al. [7] investigated the effect of adding hydrogen with diesel on performance and CO_2 emissions of a diesel engine. The analysis was carried out by varying load on engine from 0 kW to 40 kW. They had used upto a maximum of 20% hydrogen blend with diesel and emphasized that it also did not require any change in original settings of engine. They had reported that by using diesel and hydrogen blend in engine would not significantly affect engine efficiency and specific fuel consumption but it had drastically reduced CO_2 emission by 12%. Nevertheless it was also investigated that the volumetric efficiency of the engine was reduced by 6%.

Pisa et al. [9] had investigated the effect of hydrogen enriched gas upon emission pollutants of a 2 MW thermal furnace. They had reported about 35 to 40% reduction in sulfur dioxide concentration although NO concentration was increased about 10 to 17%.

3. METHODOLOGY

The methodology adopted for the present study has been demonstrated with the help of Fig. 1.

As understood by current status of fossil fuel consumption and harmful emission gases, it is very necessary to move towards alternative fuels for engines. The major issues of using fossil fuels are high consumption of fuels, in IC Engines, which are having limited reserve and harmful gases in emission which adversely affect the environment. Literature review of many international and national journal papers also support the usage of HHO gas as a secondary fuel which eventually lead to increase power and reduce emissions.

The next step is to produce the hydroxy gas, which is done by electrolysis process of distilled water. A hydroxy booster has been made as shown in Fig. 2. The booster has cathode and anode which has been supplied with 12V direct current. The electrolytes mixed with distilled water are 1-3% KOH and NaOH. The booster generates HHO gas which is then collected in a device called bubbler as shown in Fig. 3.

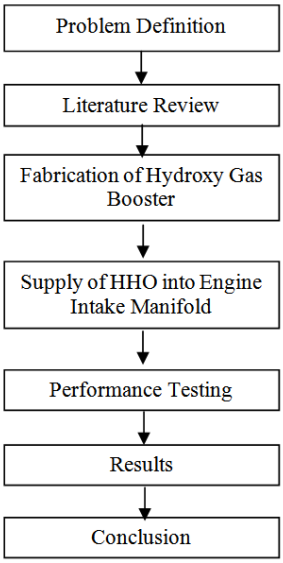

Fig. 1: Flow Diagram for Adopted Methodology

Fig. 2: Electrolyzer

Fig. 3: Bubbler

The next step is to supply this generated HHO gas to the engine intake manifold, as shown in the Fig. 4. The engine selected for the present study is shown in Fig. 5 and its specifications are as follows.

Engine specifications: Maruti Swift Petrol MPFI

Type: Four stroke, four cylinder, Inline, DOHC, MPFI petrol Engine.
Bore: 73 mm
Stroke: 72mm
Displacement: 1197cc
Compression Ratio: 10:1
Firing order: 1-3-4-2
Cooling system: Water cooled
Fuel system: Multi Point Fuel Injection

Loading Device: Powermag Eddy Current Dynamometer

Type of Loading: Eddy Current Dynamometer
Capacity: 15 HP
Torque: 4.8 kg-m
Maximum speed: 1500 rpm
Torque controller: Electronic torque exciter

Load Indicator

Torque arm length: 100 mm
Torque: Digital torque indicator in N-m

Load cell

Capacity: 50kg
Accuracy: +/- 0.2 Nm

Fuel Measuring Device: Gravimetric

Capacity: 10kg load cell
Type: Cantilever type strain gauge

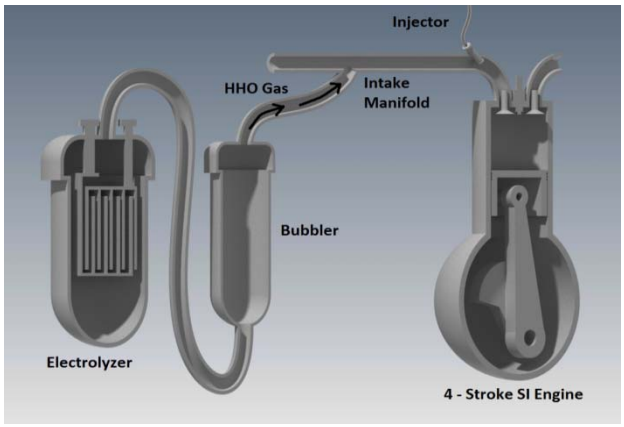

Fig. 4: Schematic Diagram for integrating hydroxy bubbler with engine

In the next step, performance analysis is carried out by varying load on engine at a constant speed of 1500 rpm. Test rig used is as shown in Fig. 6.

Fig. 5: Engine under testing

Fig. 6: MPFI Petrol Engine Test Rig

4. RESULTS AND DISCUSSION

The performance analysis was carried out on the four stroke multi cylinder SI engine before and after installing the hydroxyl gas booster. The formulae used for calculations can be found in different IC engine textbooks.

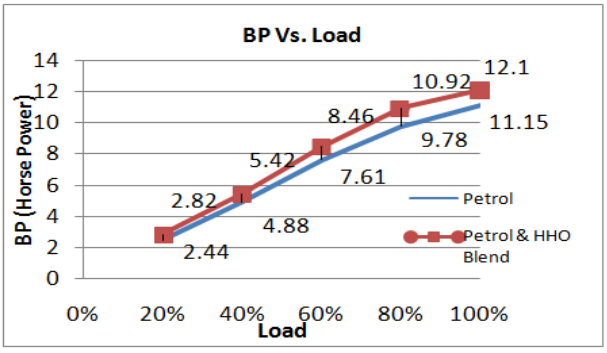

Fig. 7: BP vs. Load

The results obtained for brake power at different engine load have been shown in Fig. 7. At the same load and a constant speed, it has been observed that there is significant increase in Brake Power when HHO is used with petrol. Results have shown that there is an increase in brake power by an average of about 11.5% after installing hydroxy gas booster in the existing system. This is due to enhanced combustion characteristics by adding HHO gas.

The results obtained for specific fuel consumption at different engine load have been shown in Fig. 8. At the same load and a constant speed, from the following graph it is well clear that there is significant decrease in specific fuel consumption when HHO is used with petrol. Results have shown that there is reduction in SFC by an average of about 6.35% after installing hydroxy gas booster in the existing system.

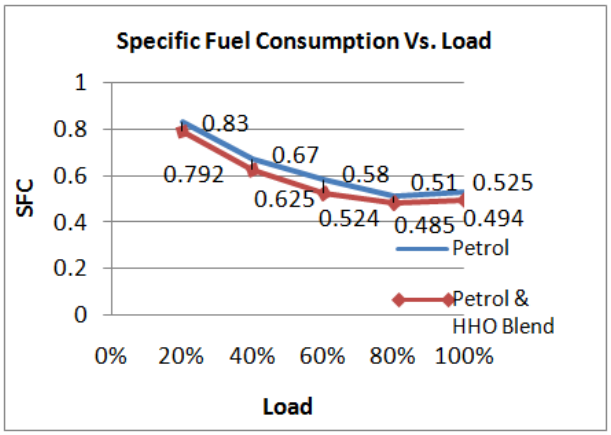

Fig. 8: Specific Fuel Consumption vs. Load

This is due to enhanced combustion characteristics by adding HHO gas. Thereof it leads to complete combustion of fuel, which is also having higher octane rating. From the results it is pretty much clear that after a certain point there will be increase in SFC. The minimum SFC is achieved when the engine is running at 80% of its rated capacity.

The results obtained for brake thermal efficiency at different engine load have been shown in Fig. 9. At the same load and a constant speed, from the following graph it is well clear that there is significant increase in brake thermal efficiency when HHO is used with petrol. Results have shown that there is an increase in brake thermal efficiency by an average of about 10.26% after installing hydroxy gas booster in the existing system. This is due to enhanced octane rating of fuel which leads to more heat liberation along with better combustion.

The results obtained for exhaust gas temperature at different engine load have been shown in Fig. 10. At the same load and a constant speed, from the following graph it is well clear that there is significant reduction in exhaust gas temperature when

HHO is used with petrol. Results have shown that there is decrease in exhaust gas temperature by an average of about 4% after installing hydroxy gas booster in the existing system. This is due to improved burning of fuel which further leads to significant reduction in NO_X emission from exhaust gas.

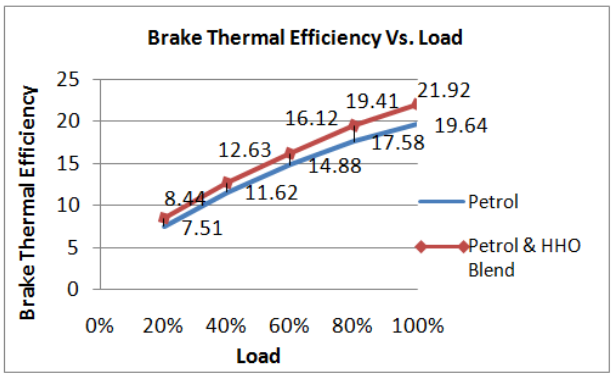

Fig. 9: Brake Thermal Efficiency vs. Load

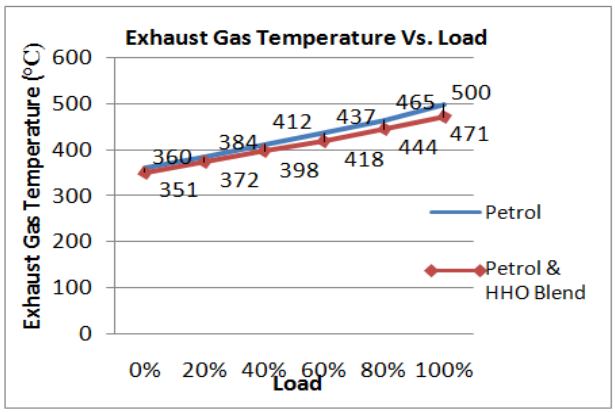

Fig. 10: Exhaust Gas Temprature vs. Load

5. CONCLUSION

In the present study experimental analysis is performed in order to investigate the effect of hydroxy gas on different performance measures of a four stroke multi-cylinder SI engine. HHO gas is generated with the help of electrolysis of distilled water in the presence of KOH and NaOH. This generated gas is supplied to the intake manifold of the engine. After installing the hydroxy gas booster with engine, following conclusions can be made :

1. The brake power of the engine has been enhanced by almost 11.5% on average.
2. The specific fuel consumption of engine has been decreased by almost 6.35% on average.
3. The brake thermal efficiency of engine has been increased by almost 10.26% on average.
4. The exhaust gas temperature from engine has been reduced by almost 4% on average. This is due to improved burning of fuel which further leads to significant reduction in NO_X emission from exhaust gas.

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