EFFICIENCY IMPROVEMENT OF SI/CI ENGINE BY USING BLEND OF HYDROGEN GAS WITH FUELS.

Graduate Project for Automotive Power Plants.

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Abstract

In order to overcome the drawbacks of the regular petroleum fuel, it is the need of time to completely or partially replace the petroleum fuel. But alternative options to petroleum fuel are having disadvantages.

An electric or compressed air driven car cannot be used where high torque is required or using hydrogen as fuel requires very costly storage equipment's. In this research work an attempt has been made to reduce the drawbacks of petroleum fuels. Electrolysis of water can give us hydrogen in form of oxy-hydrogen gas which can be used as an alternative fuel for any internal combustion engine.

Oxy-hydrogen gas is produced by electrolysis of water using caustic soda or KOH as the catalyst. Presence of oxy-hydrogen gas during combustion process decreases the brake specific fuel consumption and increases the brake thermal efficiency. Water is one of the by-products of the combustion process which also decreases the temperature of the combustion process. It is safe to use 'oxy-hydrogen gas' as it is not stored but is produced and used as and when required. The overall research carried out on engine shows improvement in the 'brake thermal efficiency' with the blend of fuel. All together it has been observed that the blend of 'oxy-hydrogen gas' and petrol instead of only conventional fuel improves the performance of the engine.

Today the whole world is facing two major problems one is increasing pollution and rapid use of fossil fuels. So, there is a need to control pollution and reduce fuel consumption. Incomplete combustion of fuel causes pollution and reduction in fuel utilization. We are looking for such source of energy which helps for complete combustion of fuel and increases fuel utilization which ultimately reduces the pollution. In order to overcome the drawbacks of the regular petroleum fuel, it is the need of time to completely or partially replace the petroleum fuel.

Key words : Electrolysis of water, Oxy-hydrogen gas, SI/CI Engine.

1. INTRODUCTION

1.1 Problem Statement

Oxy-hydrogen gas is a mixture of ‘hydrogen’ and ‘oxygen’ bonded together. Oxy-hydrogen gas is produced by electrolysis of water using caustic soda or KOH as the catalyst. Due to using ‘oxy-hydrogen gas’ in I.C. Engines during combustion process decreases the ‘brake specific fuel Consumption’ and increases the ‘brake thermal efficiency. In this process water is by-product of the combustion process which also decreases the temperature of the combustion process. It is safe to use ‘oxy-hydrogen gas’ as it is not stored but is produced and used when required. Together with ‘brake thermal efficiency’ of engine shows improvement in the ‘brake thermal efficiency’ with the blend of fuel. All together it has been observed that the blend of ‘oxy-hydrogen gas’ and petrol instead of only conventional fuel improves the performance of the engine.

1.2 Objectives

Any alternative to conventional fuels should:

[1] Increase Mileage

[2] Increase the Power & Performance of Vehicle

[3] Reduce Engine Noise & Vibration

[4] Increase Life span of Engine

[5] Increase Burning Efficiency

[6] Reduce Pollution

[7] Reduce the engine temperature

1.3 Scope

In this report we present, various measurements on a mixture of hydrogen and oxygen called HHO gas produced via a new electrolyze (international patents pending by Hydrogen Technologies Applications, Inc. of Clearwater Florida), can be used to increase the efficiency in the internal combustion engine. The measurements herein reported suggest the existence in the HHO gas of stable clusters composed of H and O atoms, their dimers H–O, and their molecules H2, O2 and H2O whose bond cannot entirely be of valence type. Need for such research arises because of the scarcity of the crude-oil resources in our mother nature for satisfying our multiplying demands. An effort to draw the prime attention of the authors to develop an alternative mechanism, which can serve as a basis for driving the automobile is tried. In order to reduce the atmospheric pollution emitted by automobiles, control devices are being incorporated in the vehicles in many countries. This has resulted in a reduced vehicle mileage to the extent of about fifteen percent. With- out the introduction of new technology, any further reduction in emission levels would be expected to extract payment in the form of further fuel economy losses. The project report investigates on study on a vehicle as well as calculations to prove efficiency improvement possible, where usage of vehicles is increasing day by day. Increase in vehicles will lead to fuel scarcity soon. Hence this may lead researchers to think about alternate fuel that can be utilized for the vehicles. We can aim to increase awareness about conventional fuels from this project which is aimed at developing a product with conventional standard that help in solving the said global issue.

1.4 Methodology

1.4.1 Methods for improving brake thermal efficiency:

Different methods used to control the emissions MPFI(Multi-point fuel injection), EGR(Exhaust gas re-circulation), PCV((Positive crankcase ventilation), evaporative emission control, oxygen sensors etc. which minimize the rate of emission through I.C. engine and gives proper combustion of fuel in engine.

[1] Magnetic Fuel Conditioner:

It has disadvantage that, if the strength of the magnet is increased it will overflow the whole tank of vehicle if the cock is kept in on position.

[2] By Oxy-Hydrogen Gas:

Electrolysis of water can give us hydrogen in form of oxy-hydrogen gas which can be used as an alternative fuel for any internal combustion engine.

1.4.2 Properties of Hydrogen as alternative fuel

Hydrogen has been considered as a fuel for I.C. Engines for more than 100 years. In 1820, Cecil was first man who recommended the use of hydrogen as fuel for engines and Rudolf Erren makes more than 1000 vehicles which run on hydrogen and fuel blends. Hydrogen has several unique properties, some quite different from conventional liquid fuels, which are summarized in Table. 1

The properties that contribute to its use as a combustible fuel are shown in Table 1.

Property	**Hydrogen**	**Gasoline (Petrol)**
Molecular weight	2.02	91.4
Stoichiometric composition in air, vol.%	29.53	1.76
Minimum energy of Ignition in air, mJ.	.02	0.24
Auto-ignition temperature, K.	858	501-744
Flame temperature, K	2318	2470
Burning velocity at NTP in air, cm s^{-1}	265-325	37-43
Diffusivity in air, $cm^2 s^{-1}$	0.63	0.08

Limits of flammability (equivalence ratio)	0.1-7.1	0.7-3.8
Density at 1 atm. & 300K, kg m^{-3}	0.082	680
Lower Heating value, MJ kg^{-1}	119.7	44.79
Lower Heating value, MJ m	10.22	216.38
Ratio of specific heat at NTP	1.383	1.05

Table 1-Combustion properties of hydrogen and gasoline. [9]

a. Wide Range of Flammability :-

Hydrogen has a wide flammability range in comparison with all other fuels. By Combustion of any fuel with an excess of air is a desirable because of it will completely burn and produces less pollutants. Wide range of fuel-air mixtures will be suitable for combustion in I.C. Engines. One of the main advantages of hydrogen is that, it needs less amount of fuel i.e. less than the theoretical, stoichiometric or chemically ideal with given amount of air for burning. Hence it is fairly easy to get an engine to start on hydrogen. Additionally, the final combustion temperature is generally lower; Fuel economy is greater, reducing the amount of pollutants, such as nitrogen oxides, emitted in the exhaust while running on lean mixture. But there is some limit to use lean mixture as it reduces power output due to a reduction in the volumetric heating value of the air/fuel mixture.

b. Low Ignition Energy :-

Hydrogen has very low ignition energy. The amount of energy needed to ignite hydrogen is about one order of magnitude less than that required for gasoline. This enables hydrogen engines to ignite lean mixtures and ensures prompt ignition. Unfortunately, the low ignition energy means that hot gases and hot spots on the cylinder can serve as sources of ignition, creating problems of premature ignition and flashback. Preventing this is one of the challenges associated with running an engine on hydrogen. The wide flammability range of hydrogen means that almost any mixture can be ignited by a hot spot.

c. Small Quenching Distance :-

Hydrogen has a small quenching distance, smaller than gasoline. So, hydrogen flames travel closer to the cylinder wall than other fuels before they extinguish. Thus, it is more difficult to quench a hydrogen flame than a gasoline flame. The smaller quenching distance can also increase the tendency for backfire since the flame from a hydrogen-air mixture more readily passes a nearly closed intake valve, than a hydrocarbon-air flame.

d. High Auto ignition Temperature :-

Hydrogen has a relatively high auto ignition temperature. This has important advantage when a hydrogen-air mixture is compressed. Generally, auto ignition temperature is an important factor in determining what compression ratio used for engine, since the temperature rise during compression is related to the compression ratio. The temperature rise is shown by the equation:

$$T2=T1(V1/V2)^{\gamma-1}.$$

where, V1/V2 = the compression ratio.

γ = ratio of specific heats.

T1 = absolute initial temperature.

T2 = absolute final temperature.

The temperature may not exceed hydrogen’s auto ignition temperature without causing premature ignition. Thus, the absolute final temperature limits the compression ratio. The high auto ignition temperature of hydrogen allows larger compression ratios to be used in a hydrogen engine than in a hydrocarbon engine.

e. High Flame Speed :-

Hydrogen has high flame speed at stoichiometric ratios. Under these conditions, the hydrogen flame speed is nearly more than that of gasoline. This means that hydrogen engines are closer to ideal engine cycle. At leaner mixtures, however, the flame velocity decreases.

f. High Diffusivity :-

Hydrogen has very high diffusivity. This ability to disperse in air is considerably greater than gasoline and is advantageous for two main reasons. Firstly, it allows the formation of a uniform mixture of fuel and air. Secondly, if a hydrogen leak develops, the hydrogen disperses fast. Thus, unsafe conditions can either be avoided or minimized.

g. Low Density :-

Hydrogen is the lightest element having very low specific volume and an extremely low density, both as a gas and as a liquid. So, efficiency will fall when hydrogen is added to the intake of an engine. Low energy density property could be a major advantage that it disperses in the atmosphere much more rapidly. Hydrogen has density of 0.08376 kg/m^3. This results in two problems when used in an internal combustion engine. Large volume is necessary to store enough hydrogen to give a vehicle an adequate driving range. Secondly, the energy density of a hydrogen-air mixture, and hence the power output, is reduced.

2. SYSTEM LAYOUT DEVELOPMENT

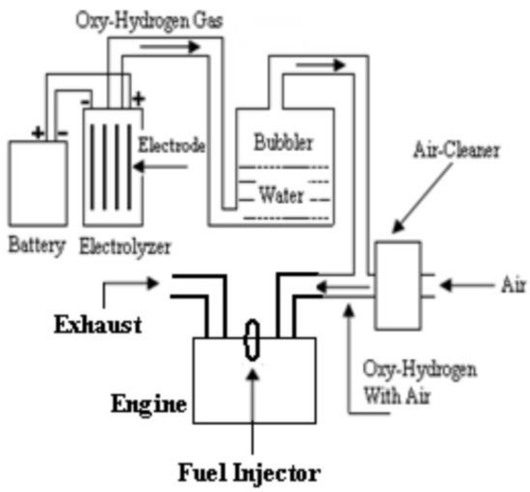

Figure 1: Block diagram of oxy-hydrogen unit mounted on engine [6]

The unit used in their research work for the generation of producer gas consists of a stainless-steel body having geometry like a cylinder with a flange for fixing the head of cylinder having same flange. The head of Pyrolizer unit has provision for introducing biomass and removal of gas produced in the unit. It also has two thermocouples, a long and a short one, the long thermocouple measures the core temperature whereas the short thermocouple measures the temperature of the gas produced at top inside the unit. Heating coils are fixed circumferentially to the pyrolizer unit from outside and insulation is provided over the unit circumferentially from outside. Scrubber tank is used to clean the gas and to condense the condensable. It is partially filled with water; gas comes from top of the tank which is taken to the bottom of water through pipe so that it passes through water. There is an outlet for removal of gas.[6] Also, there is a provision for flushing out the water from the tank. Control unit is the unit from which we can set the temperature and also control the heating. From 1500^0C to 4000^0C of inner core where there is continuous production of the gas. It requires 70 to 75 minutes to produce 700 m of gas.

3. INVESTIGATION OF ENGINE PERFORMANCE

Technical Specifications of the Engine.
Type: Tomos 4
Spark: Ignition Engine
Cycle: Two stroke, air cooled
No. of cylinder: 1
Compression ratio: 10:1
Cubic capacity: 59.3 cu cm
Cylinder bore: 42 mm
Stroke: 43 mm
Rated output: 2.2 kW(3.0 HP) @ 5400 rpm
Engine speed: 3600 rpm
Ignition timing: Variable

No hardware modification in the engine is required for the supply of Oxy-Hydrogen gas. Only an inlet is to be given for the entry of the gas into the combustion chamber. This entry is provided S.I engine and after air cleaner in case of Petrol engine, so that the Oxy-Hydrogen gas will get enough time to adhere the fuel molecules. Thus, the oxy hydrogen gas is brought inside the combustion chamber just because of engine suction pressure. Thus, the Oxy-Hydrogen usage is compatible with any of the running engine. To make the complete Oxy-Hydrogen gas unit, components required are the Oxy-Hydrogen Generator or Electrolyzer, Bubbler & Post Air Cleaner Joint. Oxy-Hydrogen Generator generates Oxy-Hydrogen gas as discussed earlier. Terminals of electrolyzer are connected to the car battery by means of two insulated wires. Insulated wires are attached to the plates by means of hard soldering. Soft solder should be avoided as due to the rise in temperature there are chances that the solder may melt, and the wires meet adjacent plate leading to generation of spark & thus causing explosion of the generator /electrolyzer. Bubbler is component used for the safety purpose in case of backfire from engine. It is filled with water, through which Oxy-Hydrogen gas can pass; also, if steam is generated in the generator is condensed inside the bubbler. Thus, it allows only pure gas to enter the engine. As its purpose is just to act as a safety device plastic bottle insufficient it also reduces the cost and even if backfire occurs the plastic bottle will tear off quickly & avoid strong blast of it. It does not allow the ignited gas to reach the generator as the water present in it extinguishes the ignited gas. [7]

To check the rate of oxy hydrogen gas generated with respect to rate of current rise, a loss of weight of electrolyzer is noted for a given period and current. Current passing through electrodes is increased from 1 to 3 amp in step of 1 amp. Figure 2 shows that with increase in the time for which the current is flowing through electrolyzer, weight of electrolyzer decreases. Larger the weight loss larger is the gas generation weight. Also, with increase in amplitude of current, the rate of generation increases. For larger gas generation, it is possible to increase the amplitude of current as well. As the engine keeps on consuming the oxy hydrogen, the level of electrolytic solution in the electrolyzer decreases which further decreases the weight of the electrolyzer. All the designs of electrolyzers were tested on different engines and all of them showed the improvement in the operating characteristics of engines when blend of oxy hydrogen is send with conventional fuel whichever may be the generation method used for production of oxy hydrogen gas, there is little effect of it as far as change in the improved performance of the engine is concern. [7]

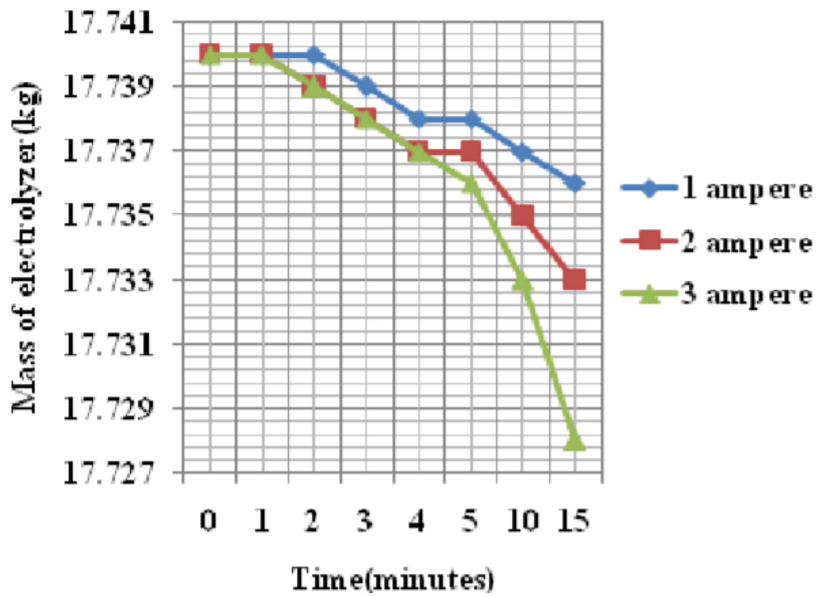

Figure 2. Graph of mass of electrolyzer v/s time.[7]

In order to investigate the change in the performance of engine with the blend of oxy hydrogen gas and conventional fuels like petrol and diesel as a fuel various load tests were conducted on the four-stroke petrol as well as diesel engine. It is nearly impossible to show the results of the entire testing carried out in this report due to space limitation; however, since amongst all the tests carried out, the diesel engine has shown grater improvements in its characteristics with generator of first method and second design. The reason for that is the high rate of oxy hydrogen generation.

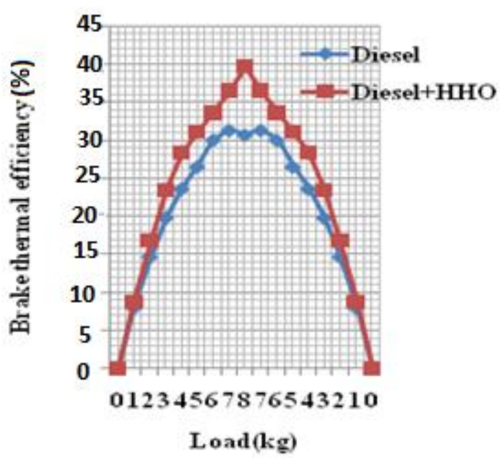

Figure 3. Graph Of Brake Thermal Efficiency(%) v/s Load(kg) [7]

From the trend of the variation shown in Figure 3, it is very clear that BSFC of the engine reduces when oxy hydrogen gas is supplied in blend with Diesel. At the maximum load of 8 kg of load during testing, almost 10 g of less fuel is required to reduce same power hour. This can be further increased by sending more amount of oxy hydrogen gas. Decrease in BSFC is because some amount of diesel is replaced by oxy hydrogen gas during the process of combustion; so some amount of required input energy is supplied by oxy hydrogen gas and the amount of diesel required to produce the equivalent energy is saved. From the graphs of brake thermal efficiency v/s load (Figure 3), it is clear that as the load on the engine increases, brake thermal efficiency further increases for the blend of oxy hydrogen and diesel. The efficiency increases by almost 10% for the blend compared to only diesel as a fuel. Increase in Brake thermal efficiency is because of increase in the brake power of the engine. Increase in the brake power is because more energy is released by the blend of oxy hydrogen gas and diesel during the process of combustion compared to energy released by only diesel.

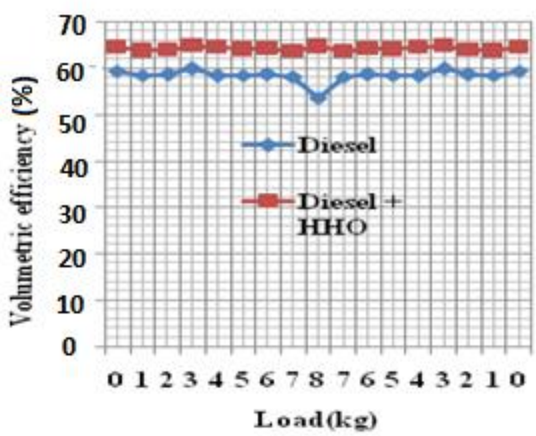

Figure 4. Graph of Volumetric Efficiency(%) v/s Load(kg). [7]

From the graph of volumetric efficiency v/s load (Figure 4), it is clear that the volumetric efficiency of the engine increases by almost 10% at a load of 8 kg when the blended fuel is sent inside the combustion chamber. Increase in the volumetric efficiency is because more volume of the mixture is entering inside the combustion chamber with respect to engine swept volume when the blended fuel is sent inside the combustion chamber. From the aforementioned discussion, it is clear that there is definitely improvement in the performance of the engine when the engine is run on the blend of 'oxyhydrogen' and conventional fuel, 'diesel' here. Further, the presence of 'oxy-hydrogen' in the combustion chamber supplies additional oxygen which leads to completed combustion of the air fuel mixture. Thus the pollution is greatly controlled as the products that would be produced due to burning of conventional fuel and are reduced due to complete combustion. Water vapor is one of the by-products of the combustion process with the blend of 'oxy-hydrogen' and diesel.[7] Presence of water in the combustion chamber also decreases the temperature of the combustion chamber. Thus there are little chances of 'detonation' which is the major factor during increased power delivery of any engine. Also formation of water vapor does not allow deposition of the carbon on the cylinder wall and keeps the combustion chamber clean which further increases combustion efficiency.

4. EXPERIMENTAL ANALYSIS

Sr. No.	Aspect	Gas Filled (ml)	Start (km)	End (km)	Mileage (km/ltr)
1	Without kit	200	12831.1	12841.8	53.5
2	Without kit	120	12841.9	12848.0	50.8
3	With kit (water)	200	12916.4	12928.5	60.5
4	With kit (water)	120	12928.5	12936.7	68.33
5	With kit (Distilled water + KOH)	200	13016.4	13117.7	64.4
6	With kit (Distilled water + KOH)	120	13097.7	13105.2	62.2

Table 2. Experimental Analysis of the oxy-hydrogen test.[8]

The above results are based on test carried out on the implementation of oxy-hydrogen gas on a TVS- scooty-pep operating on gasoline. It shows us that fuel efficiency as well as the combustion efficiency is increased. Which in turn helps in increasing the Brake thermal efficiency as well as the Volumetric efficiency.

LIMITS ON USING HYDROGEN AS FUEL

A/F based on mass: = mass of air/mass of fuel = 137.33 g / 4 g = 34.33:10
A/F based on volume: = volume (moles) of air/volume (moles) of fuel = 4.762 / 2 = 2.4:1
The percent of the combustion chamber occupied by hydrogen for a stoichiometric mixture:
% H_2 = volume (moles) of H_2/total volume
= volume H_2/(volume air + volume of H2)
= 2 / (4.762 + 2)
= 29.6% [4]

As these calculations show, the stoichiometric A/F ratio for the complete combustion of hydrogen in air is about **34:1** by mass. This means that for complete combustion, 34 pounds of air are required for every pound of hydrogen. This is much higher than the 14.7:1 A/F ratio required for gasoline. Since hydrogen is a gaseous fuel at ambient conditions it displaces more of the combustion chamber than a liquid fuel. Consequently, less of the combustion chamber can be occupied by air. At stoichiometric conditions, hydrogen displaces about 30% of the combustion chamber, compared to about 1 to 2% for gasoline.[4]

CALCULATIONS

$\eta = P/(m^{dot}{}_f * Q_{hv})$.

For Power calculations:
Considering a gasoline IC engine
We will assume typical efficiency of 35%,

For **$m^{dot}{}_f = ((bsfc(g/kw.hr)*bmep(kPa)*Vd(m^3)*n)/2*60*3.6*10^9)$**

Now brake mean effective pressure can be calculated as
$Tb(Nm) = bmep(kPa)*Vd(m^3)/(4\pi)$

For n = 1000 rpm,
Tb = 172.31 Nm
Bsfc = 232(g/kw-h)
Bmep = 1100(kPa) [3]

Hence,
$m^{dot}{}_f$ = ((232*1100*1.963*1000)/2*60*3.6*10^9)
= 1.163*10^-3 (kg/s)
Implementing $m^{dot}{}_f$ value in efficiency formula, we get,
0.35 = P/(1.63*10^-3*44*10^3) as Q_{hv} (gasoline) = 44MJ/kg
P = 17.864 kW = 23.956 hp

Considering for hydrogen as fuel,
0.35 = P/(1.63*10^-3*120*10^3) as Q_{hv} (hydrogen) = 120 MJ/kg
P = 48.72 kW = 65.33 hp

This means that using hydrogen we are confirmed to get more power output for same efficiency. But as hydrogen uses 34:1 compression ratio it is complicated to build an engine with that size.

Efficiency calculations:
$\eta = 1 – 1/(r_c^{\Upsilon-1})$
Where r_c = compression ratio,
Υ = ratio of specific heats.

For gasoline,
r_c = 14:1, Υ = 1.4.
η = 1 – 1/(14.7^0.4)
= **65.87 %** assuming constant volume process theoretically.

For hydrogen,
$r_c = 34:1$, $\Upsilon = 1.38$.
$\eta = 1 - 1/(34^{0.38})$
= **73.81%** assuming constant volume process theoretically.

Hence, we can conclude that hydrogen can be used for better efficiency as well as better power output, but as it is too complicated to use just hydrogen in IC engine due to its limitations. So, we can use hydrogen with oxygen along with the blend of gasoline to practically make this process feasible along with better performance and efficiency.[5]

5. DISCUSSION AND CONCLUSIONS

Oxy hydrogen gas has been generated by electrolysis process and producer gas by pyrolysis. Both the alternative fuels mixed with fresh air before entering the combustion chamber. BSFC, Brake thermal efficiency, speed and load are the performance parameters kept under observation. The following conclusions are drawn:

a. It is very easy to integrate both the alternative fuels with existing engine. No major hardware modification is required.

b. Combustion efficiency increases with both alternative fuels due to presence of hydrogen in the blend. Since hydrogen is present in larger quantity oxy hydrogen gas compared to producer gas, the oxy hydrogen and diesel blend has shown best combustion efficiency as a result of which larger values of BSFC and brake thermal efficiency are obtained for the same engine.

c. Presence of extra oxy in both alternative fuels helps to improve the combustion efficiency furthermore. Water vapor is one of byproduct of combustion process with oxy hydrogen and diesel blend. This decreases the combustion chamber temperature and thus decreases the chances of engine detonation. Very less amount of oxygen is available with producer gas and diesel blend hence it is not the case with this combination.

d. By using blend of Oxy-Hydrogen gas with fuel will help to maximize brake thermal efficiency and thereby increase the performance of SI/CI Engine with using small changes with set up. Also, in future scope using micro-controllers and efficient electrolysis system regular vehicles can be made to operate partially on hydrogen at different speeds. The programming in micro-controller itself decides the hydrogen injection duration by sensing the speed of the vehicle.

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