INCREASING PERFORMANCE OF

INTERNAL COMBUSTION ENGINE

BY ADDING

OXY-HYDROGEN GAS

Prepared by

Mechanical engineer

Dana Latif Mohedin

Investigations on:

- Generation methods for oxy-hydrogen gas
- It's blending with conventional fuels
- It's effect on the performance of internal combustion engine

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 cars cannot be used where high torque is required or using hydrogen as fuel requires very costly storage equipments*.

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. This research paper discusses ***various methods designed for the production of oxy-hydrogen gas***. Later ***blend of 'oxy-hydrogen gas' and petrol or diesel is used instead of only petrol/diesel to study the influence of the 'oxy-hydrogen gas' on the performance of the internal combustion engine***. Oxy- hydrogen gas is an enriched mixture of 'hydrogen' and 'oxygen' bonded together molecularly and magnetically. 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 also ***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. Together with 'brake thermal efficiency' 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***.

INTRODUCTION

As we know sources of petroleum are ***limited*** and by the present state of its usage it will ***deplete in near future***, also their concentrations are limited to some of the nations therefore their ***monopoly*** will ever exist. Also, due to ***global warming***, *coastal areas are getting submerged* and burning of petroleum fuel will add to *green house gases*. The cost of petroleum products are high and hence are *unaffordable to most of the people* in most developing countries. Major *pollutants causing acid rains* are the byproduct of combustion. How much we try to compensate with an alternative fuel for our cars like cars working with electric motors, solar panels, but the bottom line is that we are still lagging behind in the technical aspect compared to petroleum fuels. So not to compete with petroleum fuels but to help petroleum fuels to exist longer life in turn help to survive this ever demanding automobile industry. Mindset of the vehicle user or buyer is to have a vehicle with decent looks, greater torque and at the same time better mileage. But unfortunately, even with the latest techno- logy, it is difficult to achieve the golden mean between them. So in order to conserve petroleum fuels for future and to eliminate the aforementioned limitations, there is a need of alternative and innovative fuel.

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. In this research work ***different methods for the generation of oxy- hydrogen gas*** are discussed and also ***influence of 'oxy- hydrogen gas' blended with conventional fuel*** like petrol and diesel is studied on the ***performance of the four stroke internal combustion engine***.

INTRODUCTION AND PROPERTIES OF OXY- HYDROGEN GAS

Oxy-hydrogen is an enriched mixture of hydrogen and oxygen bonded together molecularly and magnetically (Brown, 1978). Oxy-hydrogen gas is produced in a common-ducted electrolyser and then sent to the i*ntake manifold* to introduce into *combustion chamber* of the engine. Oxy-hydrogen gases will combust in the combustion chamber when brought to its auto-ignition or self ignition temperature. For a stoichiometric mixture at normal atmospheric pressure, auto-ignition of oxy hydro- gen gas occurs at about 570℃. The minimum energy required to ignite such a mixture with a spark is about 20 micro joules. At normal temperature and pressure, 'oxy-hydrogen gas' can burn when it is between about 4 and 94% hydrogen by volume. When ignited, the gas mixture *converts to water vapour and releases energy*. The amount of heat released is independent of the mode of combustion, but the temperature of the flame varies. The maximum temperature of about 2800℃ is achieved with a pure stoichiometric mixture, about 700℃ hotter than a hydrogen flame in air. Oxy-hydrogen gas has very high diffusivity. This ability to disperse in air is considerably greater than gasoline and it is advantageous in mainly two reasons:
Firstly, it facilitates the formation of *homogeneous air fuel mixture* and ***secondly***, if any leak occurs *it can disperse at rapid rate*. Oxy hydrogen gas is very low in density. This results in a storage problem when used in an internal combustion engine.

METHODS OF OXY HYDROGEN GAS GENERATION

There are two general methods which are used in this research work for the generation of oxy-hydrogen gas. The first method (Saed and Ammar, 2011) makes use of the basic principle of ***faradays law***. An electrical power source is connected to two electrodes, or two plates typically made from some inert metal such as platinum or stainless steel which is placed in the water. In a properly designed cell, hydrogen will appear at the cathode (the negatively charged electrode, where electrons enter the water) and oxygen will appear at the anode (the positively charged electrode). Assuming ideal faradic efficiency, the amount of hydrogen generated is twice the number of moles of oxygen and both are directly proportional to the total electrical charge conducted by the solution. Following are the reactions that normally take place at cathode and anode:

Cathode (reduction): $2\ H_2O + 2e \rightarrow H_2 + 2\ OH$

Anode (oxidation): $4\ OH^- \rightarrow O_2 + 2\ H_2O + 4\ e^-$

Overall reaction: $2\ H_2O \rightarrow 2\ H_2\ (g) + O_2\ (g)$

In the second method the resonance is produced inside water molecules between the electrodes by DC pulses. This alteration at natural frequency of water causes enormous electrical force to break the bond between the hydrogen and the oxygen and they freed as gas molecules which are magnetically coupled to each other. Need lees to say in both the methods, we have used an electrolyser for the generation of the oxy-hydrogen gas.

Two different types of electrolyzes were tested with the first method of obtaining oxy hydrogen gas.

In the first design the electrodes are made up of 216 ‘stainless steel plates’ with width = 100 mm, length = 160 mm and thickness = 1 mm. The plate array is supported with the help of two carbon rods, one at the top and the other at the bottom. The plates are separated with the help of Teflon washers with a gap 1.6 mm between them as shown in **(Figure1)**. *It has been observed that if the gap between electrodes is more than this, then the gas generation rate decreases and if the gap between the electrodes is less than this, then there are chances of current to jump across the electrodes giving spark which is dangerous and may result in blast of electrolyser*. The assembly of the electrodes is placed in the plastic container. The container is filled with the electrolytic solution which consists of *distilled water* and potassium hydroxide. *Distilled water will keep the electrodes clean during the process of gas generation* and KOH is added to make the distilled water conductive.

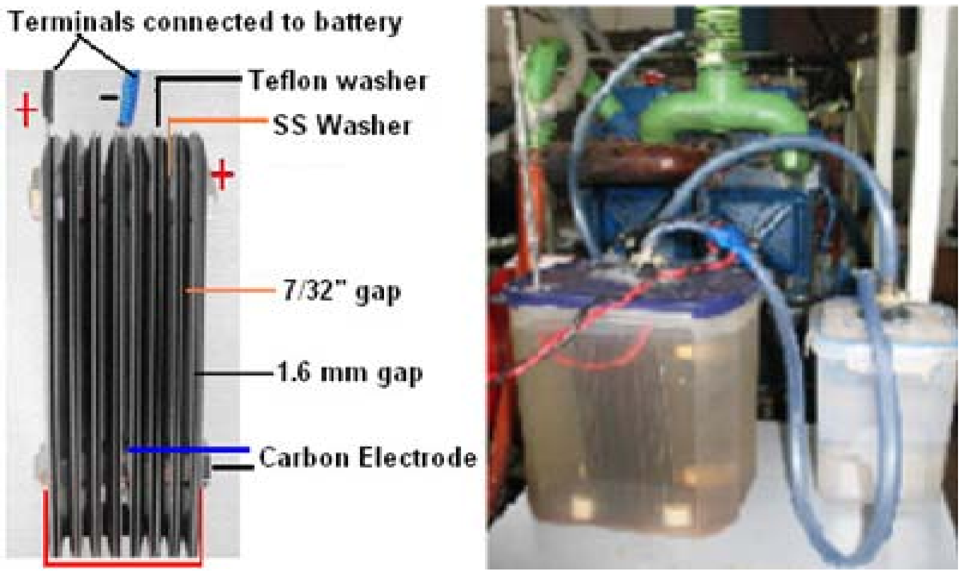

Figure 1. Arrangements of electrodes in first design of electrolyser.

In the second design (**Figure2**), two changes were made. Instead of using plastic container *a 304 'stainless steel container' of same capacity is used which itself is acting as a cathode during the process of electrolysis*. The anodes are also changed from the first design; they are of *304 'stainless steel plates'. Reason opting for 304 SS is that 304 SS is having more resistance to corrosion as compared to 216 SS*. Also as the container itself is becoming cathode *the cathode area is increased, which gives larger gas generation compared to first design*. Also this design *minimizes the chances of accidents due to explosion of oxy hydrogen gas*. The electrolytic solution remains the same as used in first design.

Figure2. Arrangements of electrodes in second design of electrolyser.

In the second method (Saed and Ammar,2011) oxy hydrogen gas generation, dielectric breakdown of water molecules is carried out by *creating resonance of 42 MHz which is equal to natural frequency of water* in water by electrical circuit consisting of resisters, timer circuits, bifilar inductors and mosphates to produce pulsating DC output. The pulsating DC output is given to set of ***9 tubes in tube electrodes made up of 316 SS with a radial gap of 0.6615 mm***. More, the gap lesser will be the generation rate and vice versa. The array of electrodes is kept in a container of same size used in first method. ***There is no need of electrolyte in this method*** (**Figure 3**); also, no current is admitted to the water; hence, ***we can even use tap water*** in this method for generation of oxy hydrogen gas.

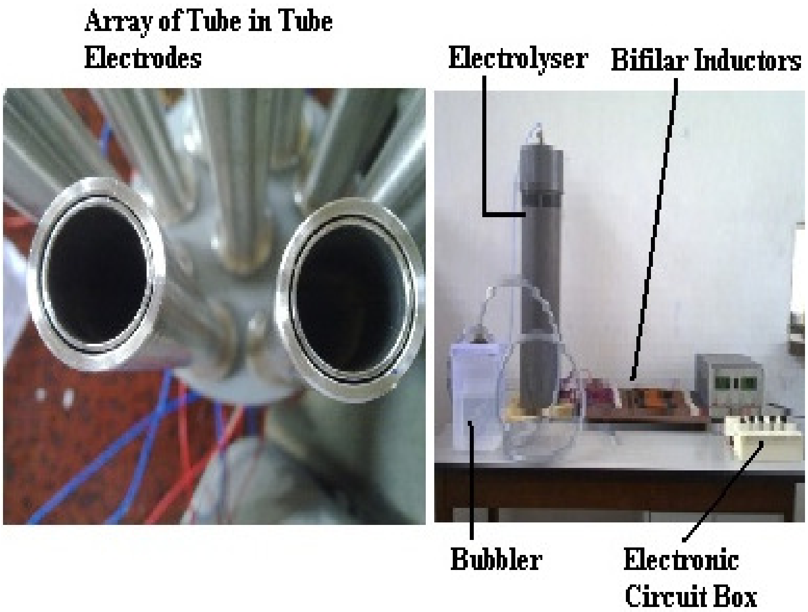

Figure3. Arrangements of electrodes in second method of electrolyser and other components.

COMPARISON BETWEEN METHODS OF OXY HYDROGEN GAS GENERATION AND THEIR IMPLEMENTAION ON ENGINE

Comparison between the methods has been done on **four factors**, *first* **the rate of generation of oxy hydrogen gas** and *second* is the **increase of temperature during the generation**; *third* factor is **safety of oxy hydrogen generator** and *fourth* factor is its **implementation on internal combustion engine**.

Rate of gas generation is concern the second design in the first method is proven to be the best amongst all designs. The reason for that is the *increased cathode area during the process of generation*, which draws more current from the source (12V battery) leading to more gas generation. The generation rate in the second method is observed to be least amongst all.

Increase in temperature of gas generator is concern, the second method that is generation by resonant DC principle registered least increase in the temperature of generator. *The method which is giving large rate of gas generation gives highest rate of temperature rise which makes it difficult to handle*.

Safety of gas generator is concern *the second method is safest* and the first method is bit risky. However, the second design of the first method takes care of safety of gas generator by itself.

Implementation of generator to any engine is concern, *all the designs are easy to connect to any engine, petrol or diesel*.

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 after the air cleaner and before the carburetor for the **S.I engine** and after air cleaner in case of **diesel engine** so that the ‘oxy-hydrogen gas’ will get sufficient time to adhere the fuel molecules. So 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 ‘electrolyser’, ‘bubbler’ and ‘post air cleaner joint’*. Oxy-hydrogen generator generates oxy-hydrogen gas as discussed earlier. As tested on four cylinder engine, *one electrolyser of small size is insufficient to provide the necessary quantity of gas; hence two generators may be used*. Terminals of electrolyser 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 come in contact with adjacent plate leading to generation of spark and thus causing explosion of the generator (Bapat et al.2009, 2010; Ghag et al., 2009, 2010; Kale et al., 2010, 2011).

Bubbler is component used for the safety purpose in case of backfire from engine. It is filled with water, through which ‘oxy- hydrogen gas’ is allowed to 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 is sufficient, it also reduces the cost and even if back fire occurs, the plastic bottle will tear off quickly and 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.

More constructional details of the assembly and flow of ‘oxy-hydrogen gas’ through; the circuit is given in Figure 4.

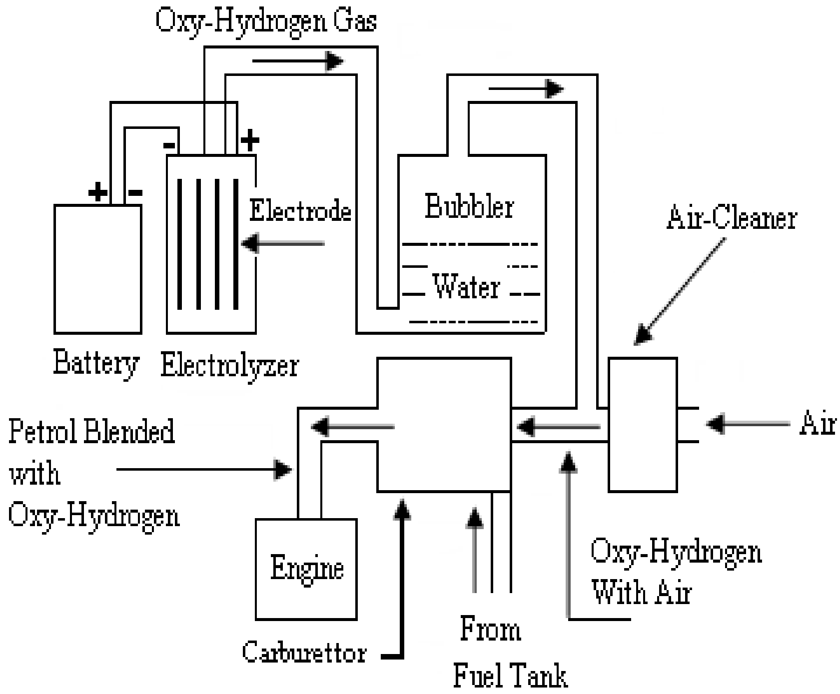

Figure 4. Block diagram of oxy-hydrogen unit mounted on engine.

INVESTIGATION OF ENGINE PERFORMANCE

To check the rate of oxy hydrogen gas generated with respect to rate of current rise, a loss of weight of electrolyser is noted for a given period of time and current. Current passing through electrodes is increased from 1 to 3amp in step of 1amp. (**Figure5**) shows that with increase in the time for which the current is flowing through electrolyser, weight of electrolyser 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 electrolyser decreases which further decreases the weight of the electrolyser. All the designs of electrolysers 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. 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; among 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.

Following are the performance graphs obtained from the test conducted on the four stroke twin cylinder diesel engine. **Brake specific fuel consumption**, **Brake thermal efficiency**, **volumetric efficiency and load** are the parameters which were kept under observation during the tests.

From the trend of the variation shown in (**Figure6**), 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, almost10g of less fuel is required to produce 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 (**Figure7**), 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.

From the graph of volumetric efficiency v/s load (**Figure8**), 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 ‘oxy- hydrogen’ 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. 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.

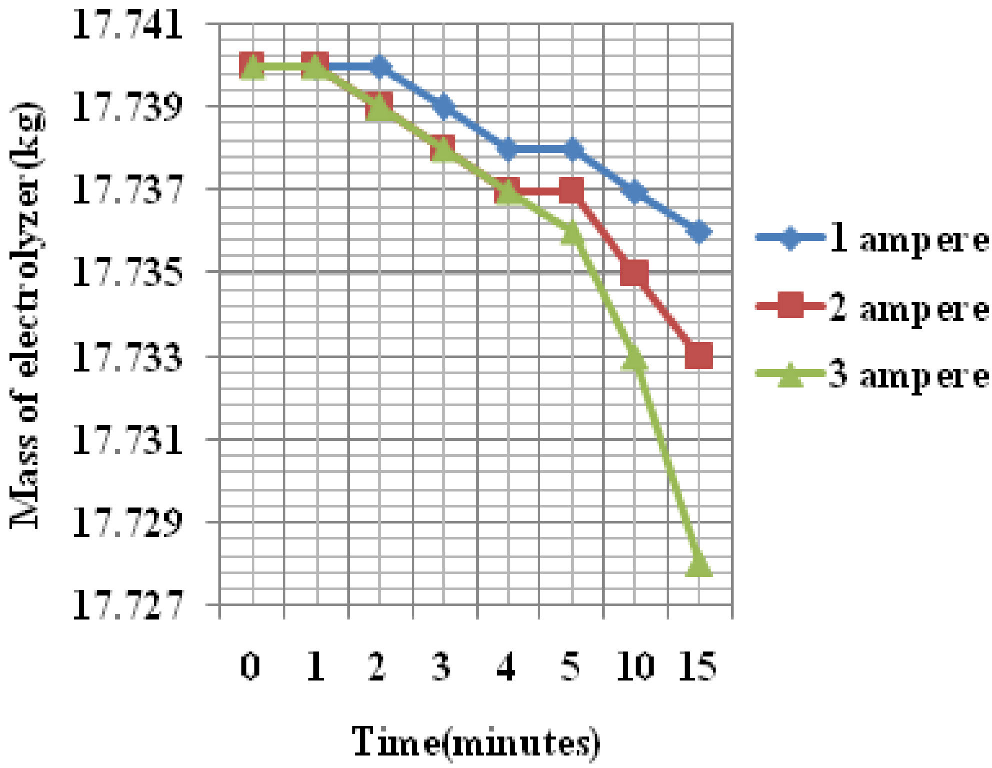

Figure 5. Graph of mass of electrolyser v/s time.

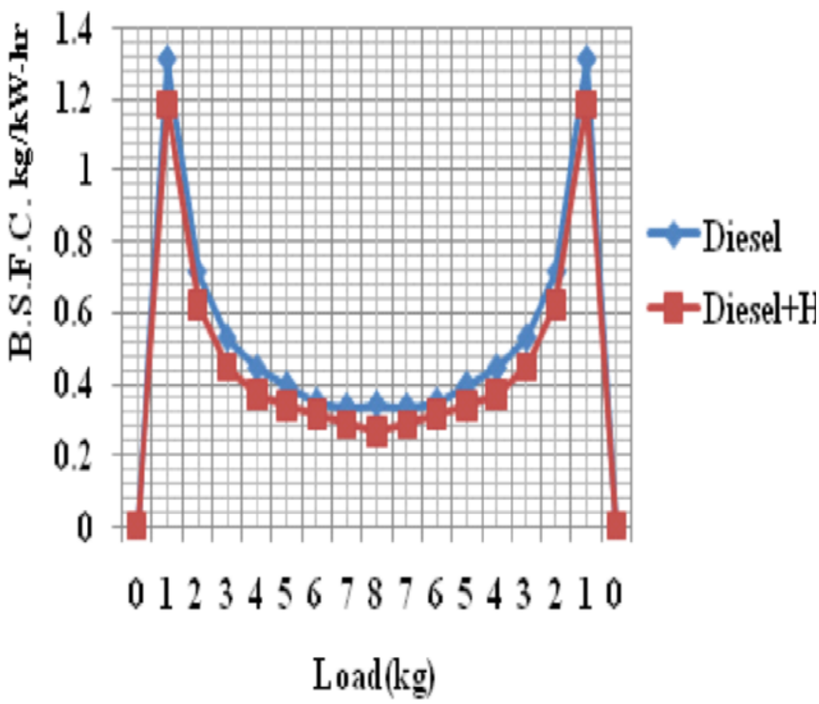

Figure 6. Graph of brake specific fuel consumption in kg/kW-h v/s load in kg.

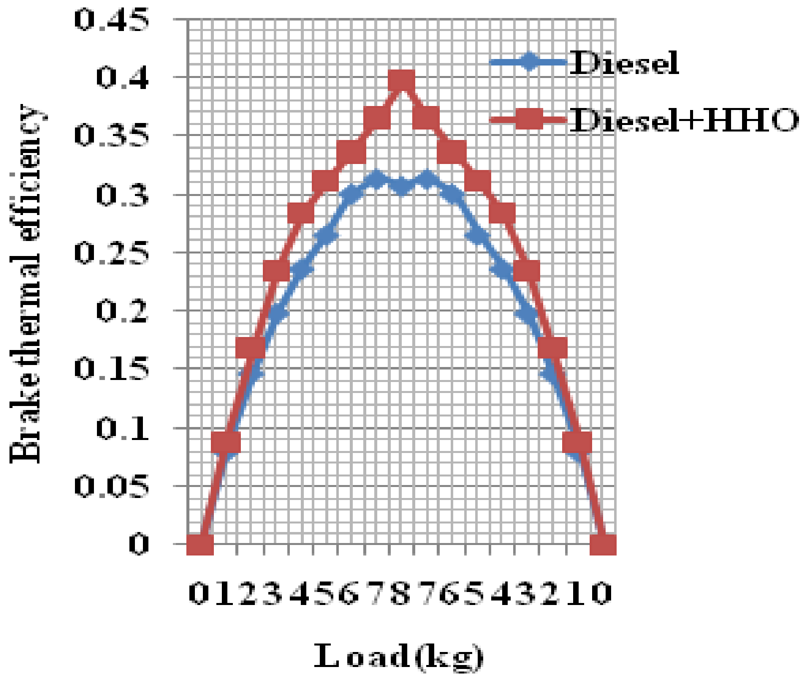

Figure 7. Graph of brake thermal efficiency in percent v/s load in kg.

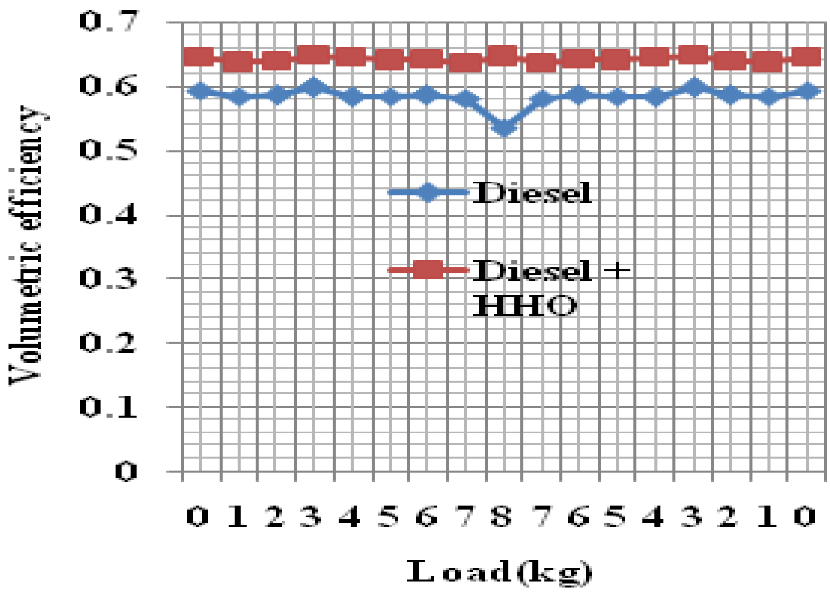

Figure 8. Graph of volumetric efficiency in percent v/s load in kg.

REFERENCES

Heywood JB (1988). "Internal combustion engine fundamentals", Tata McGraw Hill Publishing Company Limited, McGraw Hill Company Limited, Newyork.

Brown Y (1978). Brown's Gas, United States Patent, US Patent 4014, 777; March 28, 1978.

Saed A, Ammar MAA (2011). "Effect of HHO gas on combustion emission in gasoline engines", Int. J. Fuel, 90 (20110, 3066-3070).

Bapat P, Gore G, Shinde S (2009-10). '*Design, Fabrication and Testing of Oxy hydrogen generator and its implementation on engine-Stage 1*';Final year project report, Finolex Academy of Management & Technology, Ratnagiri; University of Mumbai; 2009-10.

Ghag S, Karekar V, Ketkar N (2009-10). '*Replication of Stan;ey Mayers Water Fuel Cell working on resonant DC principal-Stage 2*';Final year project report, Finolex Academy of Management & Technology, Ratnagiri; University of Mumbai; 2009-10.