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HHO Generator – An Approach to Increase Fuel Efficiency in Spark Ignition Engines

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ABSTRACT

This paper is all about designing an efficient Hydrogen-Hydrogen-Oxygen (HHO) generator, that produces Hydroxy gas which can be used to increase the fuel efficiency in an internal combustion engine. In a combustion engine, high pressure products of combustion expand through a turbine or a piston in order to generate power. In this scenario the high pressure products act as a working fluid. Currently there are three types of combustion engines in practice; Spark ignition engine, Diesel engine and Turbine engine. In these engines the fuel burning process seems to be very primitive. Hence, unburned fuel remains after the burning process. This causes the air pollution which is one of the biggest challenges that researches face in the automobile industry. HHO generator is an efficient approach that used to increase the fuel efficiency in a combustion engine by increasing the energy produced per mole of fuel during the ignition process. As a result the amount of unburned fuel in a combustion engine was reduced. The proposed approach is based on an ordinary HHO generator. Although people use HHO generators in practice a very little research has been carried out in implementing an efficient system. In this research we mainly focused on finding an efficient configuration of an ordinary HHO generator that is efficient than an ordinary system. Here the generator was tested under several conditions in order to determine a convenient design for an efficient HHO generator. An efficient/optimal system is supposed to produce a large volume of Hydroxy gas using a very little power. Therefore, such a system will be able to increase the power of a spark ignition engine while reducing the air pollution.

Key words: HHO, Hydroxy generation, electrolysis, internal combustion engine, spark ignition system

INTRODUCTION

A number of factors affect the fuel consumption of an ordinary vehicle, for example driving behaviours such as acceleration, speed, traffic and road conditions, vehicle conditions etc. Concerning the above factors, fuel price and environmental pollution the performances of an ordinary Internal Combustion Engine (ICE) has to be improved.. In practice, ICEs used in vehicles are divided into three categories, i.e. Spark Ignition Engine, Diesel Engine and Gas Turbine Engines. Spark Ignition Systems are widely used in automobiles. Here, petrol (gasoline) and diesel are highly used as the preliminary source of fuel [1-2]. Throughout this research we have only focused on the spark ignition systems which use gasoline as the preliminary source of fuel. In spark ignition systems an amount of vaporized fuel is mixed with an appropriate amount of air and these engines are designed to ignite the air-fuel mixture at the optimum instant. The flammability range of Gasoline is 1.4% to 7.6% of the volume. Hence, every pound of air should mix with 0.224g to 1.216g of vaporized gasoline in order to have a better combustion. If more vaporized gas is fed into the system, it may leave some unburned/partially burned fuel in the piston chamber as shown in Fig. 1. This unburned/partially burned fuel is one of the main pollutants that originate from conventional Hydrocarbon fuel. Carbon Monoxide (CO), Oxides of Nitrogen (NOX) and smoke are the main pollutants produced by this process. The unburned/partially burned fuel causes in increasing the exhaust emission of an engine which results in reducing the efficiency of the engine [3-4]. In order to decrease the amount of exhaust emission it is necessary to increase the thermal efficiency of the engine.

In recent years, researches have focused in enhancing the engine performances and emission. Concerning the efficiency, authors in [5] have introduced the Corona Ignition System for gasoline engines. In this approach, a new igniter tip to the conventional spark plug was introduced so that the flame propagates into more area than a traditional spark plug inside the ignition chamber. In 2014 the researches has introduced a new source of gasoline to increase the fuel efficiency of a Spark Ignition System [5], which is costly and very difficult to implement in practice.

In the proposed approach, we use Hydroxy gas as an additional source of fuel. This gas was mixed with air before feeding into the combustion chamber [6]. Hydroxy gas is also known as HHO, Brown's gas, Water gas and Green gas. HHO stands for Hydrogen-Hydrogen-Oxygen. As it name implies the Hydroxy gas consists with 2:1 particles of hydrogen and oxygen. The basic idea of this HHO production process is to separate the hydrogen and oxygen atoms in a water molecule. Output of this HHO process gives a mixture of hydrogen and oxygen that gives the name as oxyhydrogen. HHO can be generated through electrolysing the water. In this process the water molecules dissociate using two electrodes as shown in Fig. 2. The efficiency of the electrolysis process increases with the purified water i.e. water with less impurities. Rainwater, spring water and tap water has a considerable amount of impurities. A typical analysis will illustrate those minerals, suspended solids and other contaminants. When this impure water subjected to electrolysis, the impurities will deposit as brown, black and green substances. These impurities may cause to clog up the electrodes as well. In order to overcome this dilemma, distilled water i.e. water without impurities was used in the electrolysis process [7].

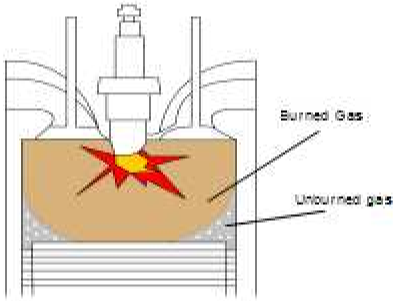


Fig.1 Flame Propagation in the chamber

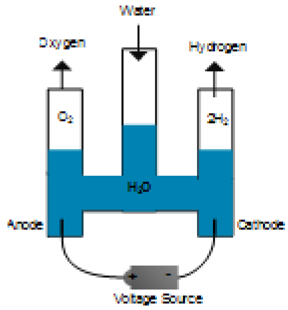


Fig. 2 Water electrolysis process

As shown in Fig. 2, whenever the system is powered up water molecules dissociate into hydrogen (H_2) and oxygen (O_2) were they emits as gases from the cathode and the anode respectively. The stoichiometric equation of this process can be expressed as in (1).

$$\text{Electrolysis: } 2H_2O \rightarrow 2H_2 + O_2 \quad (1)$$

$$\text{Combustion: } 2H_2 + O_2 \rightarrow 2H_2O \quad (2)$$

The gas produced in the electrolysis process, i.e. HHO will combust when it is brought to its ignition temperature. For a stoichiometric mixture in normal atmospheric pressure the ignition occurs at 570 ^{0}C. The energy required to ignite such a mixture is about 20 µJ. The burning process starts when the percentage of Hydrogen is between 4% - 95% of the volume of the HHO mixture. During the HHO ignition, the gas mixture releases energy and it converts into water vapour which causes to sustain the reaction in (2). The energy produced by this ignition process is 241.8 kJ, for every mole of HHO burned. The amount of heat generated in this combustion process varies according to the mode of the combustion engine [8]. In practice HHO gas can be introduced as a highly ignite source of power which will provide much higher energy compared to an ordinary ignition process in a combustion engine.

In practice HHO generator can be divided into two types based on their construction i.e. wet cell and dry cell. Two electrodes and a set of neutral plates are used in a typical wet cell. These plates are interconnected together as shown in the Fig. 3. Here, the plates are enclosed inside the electrolyte and the supply is connected to the edge of two electrodes. In this design the electrodes and the neutral plates are fully submerged in the electrolyte [9]. So that the O_2 gathers around the positive electrode starts to react with the metal plates used in the system which causes to corrode the plates eventually. Also, here the, heat dissipation in the system is low compared to the dry cell configuration. As if, the heat of the system gets increased as long as the generator runs which cause in producing water vapour. The water vapour will get mixed with the HHO gas and as a result efficiency of the system decreases [10]. Due to these failures the dry cell has become much more popular among the public [11]. In this design the above mentioned drawbacks are well considered and hence, the efficiency of the dry cell has become much higher compared to the wet cell.

In a dry cell, plates and the connections are sealed from the wet area. A typical dry cell generator is shown in Fig. 4. As shown each plate in the generator comes with a gasket to prevent leakage of water. Here, electrolyte was stored in a tank connected to the generator. The HHO gas generated here is served back into the same tank. In this process the electrolyte circulates through the system due to its gravity. Once the tank is filled with HHO gas, it puts pressure on the electrolyte which will help to make the flow. In this design the heat generated inside the system is less than the wet cell generator and also due to the circulation the heat generated inside the system get reduced. So that in this design the HHO gas generates with much higher efficiency. In addition it consumes less amount of current required for a cycle of HHO gas production. Compared to wet cell, the dry cell system requires less maintenance, there is no excessive heat generated i.e. less amount of wasted energy, less oxidation i.e. corrosion of electrodes get reduced, requires less space for an improved design than the wet cell design and it is more robust and durable.

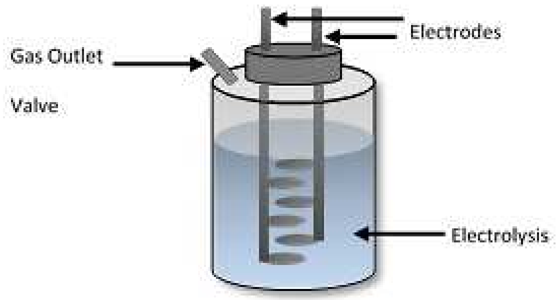


Fig. 3 Wet Cell

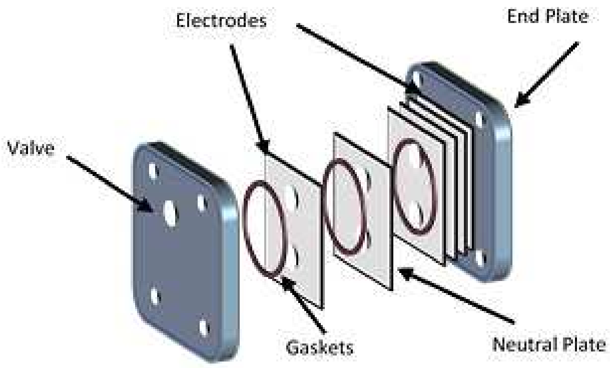


Fig. 4 Dry Cell Concept

PROPOSED APPROACH

The complete block diagram of the proposed HHO generator is shown in Fig. 5, which is a redesign of an existing HHO generator [12-14]. As shown in Fig. 5 inlet valve is used to feed water to the generator while the outlet feed out the HHO gas. Two end plates are used as insulators, also it helps to assemble the system using nut and bolts. The electrodes are used for the electrolysis process while the gaskets are used as insulators in between the electrodes and the neutral plates. Between plates the gap inhibits due to gaskets form water and gas filled chambers. Once the supply voltage is applied to the system each of the neutral plates will get charged and the electrolysis process occurs in each chamber inside the generator.

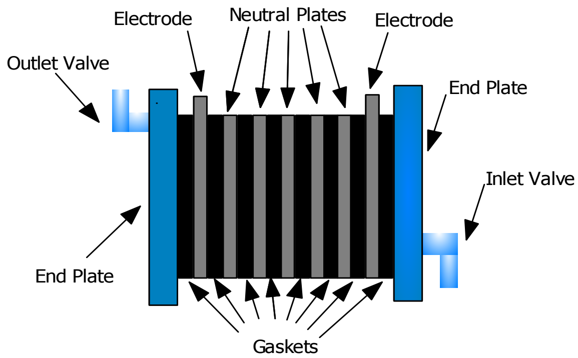


Fig. 5 Cross Sectional view of the proposed HHO generator

The electrolyte used in this process is distilled water. In order to increase the efficiency of the HHO generation a catalyst has been mix with the distilled water. This catalyst acts as an ionizer and increase the conduction of electricity through the generator. Commonly used catalysts in HHO generation are Potassium Hydroxide (KOH), Sodium Hydroxide (NaOH), Sodium Chloride (NaCl), Baking Soda (NaHCO), Sulphuric Acid (H_2SO_4), Vinegar (CH_3CO_2H) and Sodium Sulphate (Na_2SO_4). The best choice of catalyst judge by its ability to remains unchanged during the production of HHO. That means the ideal catalyst is a substance that enables the reaction of electrolysis process to increase the flow of current without becoming a part of the reaction.

Na_2SO_4 does produce H_2 and O_2 at the anode and cathode. Also a neutral solution of Na_2SO_4 remains unaltered by the electrolysis. These neutral solutions cause to reduce the HHO production which makes the Na_2SO_4 a weaker solution and also it causes to turn the water into a brown/red substance which makes this solution unsuitable. Vinegar should select considering the percentage of Acetic Acid it contains. Best is to select vinegar with 5% to 10% solution of Acetic Acid. When subject vinegar as the catalyst in HHO production it will act as a cheaper solution. But the Acetic Acid contains which has a boiling temperature of 118 ^{0}C cause to add the vaporized Acetic Acid with the HHO gas in addition to the water vapour. This makes the produced gas stinky. In addition electrolysis reaction with Acetic Acid may produce gases like Ethane and CO_2 which makes the electrolysis to corrode [15]. H_2SO_4 and NaHCO are also produce substances during the electrolysis process and also cause to corrode the metal plates [15-16].

From the experimental tests, it has proven that KOH and the NaOH is the best convenient catalyst to be used in the water electrolysis process [7]. KOH solution is much more efficient than the NaOH and it leaves the HHO cell cleaner [17]. Considering these factors thoroughly, KOH has been used in the proposed system as the catalyst.. Due to the high durability and less reaction with electrolytes, the end plates were constructed using Fibreglass. Fibre is a material which has a higher resistance to oxidizing and also the production consist with a solid surface. In making the electrodes, neutral plates and valves, Aluminium/Zinc coated iron and Stainless Steel was used. Corrosion rate of Al with KOH is 261.92 mpy (mile per year) for 1M of KOH and for the Stainless Steel it is 1.882 mpy for the same concentration of KOH [18].

The gaskets used are selected considering the maximum value of temperature they can endure. As a matter of fact at least these gaskets should operate under 100 ^{0}C of temperature. The complete system of the HHO generator is consists with a bubbler and a reservoir. The reservoir is filled with the electrolysis (distilled water and the catalyst) and connected to the generator. The produced gas, HHO was directed to the bubbler which acts as a gas storage as shown in Fig. 6. Initially the bubbler is filled with water and when it gets filled with HHO gas the excess of water was directed into the reservoir. This makes the HHO generation a circular process.

The process of electrolysis can by increase by introducing an extra electrode in the middle of the cell, which causes to increase the production of HHO than using two electrodes. The modified design is shown in the Fig. 7. In this research, two HHO generator designs were tested to determine the most efficient method. Some pictures of the real implementation are shown in Fig. 8.

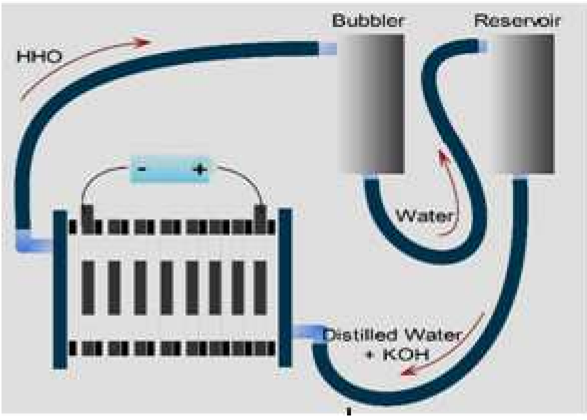


Fig. 6 HHO generator system with bubbler and the reservoir

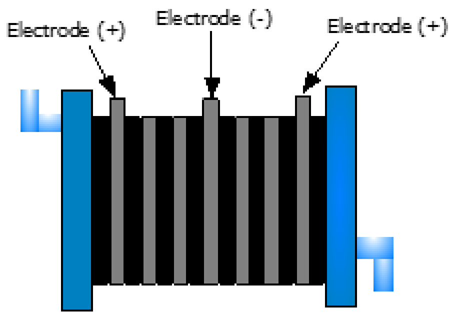
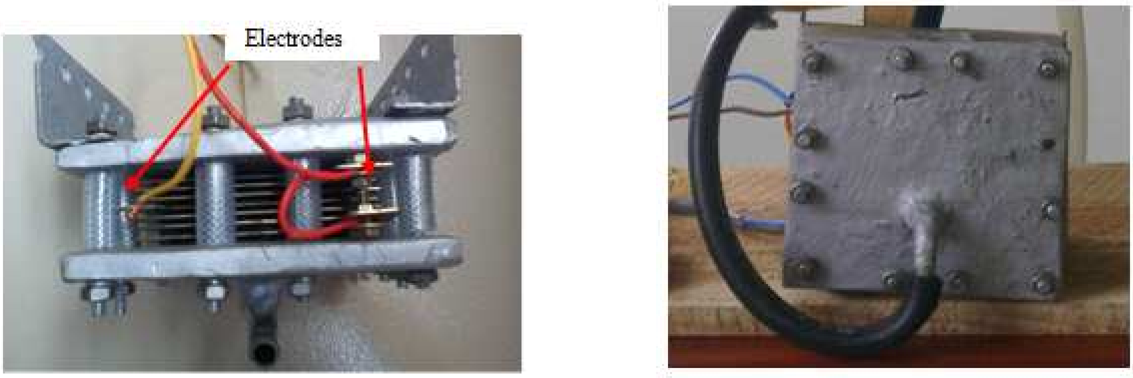


Fig. 7 HHO generator with three electrodes applied



(a) **(b)**

Fig. 8 (a) Top view of the proposed HHO generator, (b) Front view of the proposed HHO generator

OBSERVATIONS AND RESULTS

In the first implementation, the electrodes, neutral plates and the valves were designed using zinc coated iron. The generator was powered up for 24 hours with a 30g of KOH mixed in 500 ml of water. It was observed after the test that zinc coated iron used in the generator causes to corrode the metallic areas during the electrolysis process. Hence, in order to prevent this dilemma each metallic part in the design was built using stainless steel for further analysis.

As the second step, the designed generator was tested under various conditions and the obtained results are shown in Table-1. Here, the generator was tested with two electrodes and three electrodes separately for the same concentration of KOH and water as in the previous experiment. The results observed are tabulated in Table- 2.Here; the designed was tested by varying the distance between the plates and as well as the number of electrodes used for the particular design in order to observes the variations in the current flow. For the above experiments, the variation of temperature was measured and the results are shown in Table - 3. Each condition was tested only for a production of 1ℓ of HHO gas. In this experiment the initial temperature of the design was measured and was 25 ^{0}C. The deviation of the temperature as a percentage was observed for 5mm and 2.5mm distances between the plates. The deviation was calculated using the equation (3) and observations are given in Table - 4. All the experiments were conducted with 12V DC supplies which is equal to the voltage inhibits across the terminals of a battery used in an ordinary vehicle. Also the initial condition in each experiment was measured to maintain a consistent among all experiments.

Fig. 9 Corroded Zinc coated iron plate

Table -1 Dependency of the Distance between the Plates Using the Two Electrode Method

Distance between plates	Production of HHO	Maximum current flow	Time taken
5 mm	1 ℓ	1.8 A	20 min
2.5 mm	1 ℓ	6 A	4 min

Table -2 Production of HHO and Current Consumption with Number of Electrodes

Number of electrodes	Production of HHO	Maximum current flow	Time taken
2	1 ℓ	2 A	20 min
3	1 ℓ	6 A	4 min

Table -3 Dependency of the Temperature

Distance between plates	Production of HHO	Amount of Temperature increased
5 mm	1 ℓ	15 ^{0}C
2.5 mm	1 ℓ	5 ^{0}C

Table -4 Deviation of Temperature as a Percentage

Distance between plates	Deviation of Temperature as a %
5 mm	50%
2.5 mm	16.67%

$$\text{Deviation of Temperature} = \frac{|\text{Practical Observation} - \text{Initial Condition}|}{\text{Initial Condition}} \quad (3)$$

Results in Fig. 10 shows that the time taken to produce HHO using two electrodes is much greater than using three electrodes for the generator. Also according to the graph less time is taken in producing same amount of HHO using a predetermined amount of electrolyte for a small distance between plates. In this experiment three electrode method was tested only for minimum distance (2.5 mm distance) between the plates. According to the Fig. 11(a) the maximum amount of current drawn by the generator is inversely proportional to the distance between the plates of the generator. It reveals that small distance between the plates cause to draw large amount of current and cause to increase the production of HHO gas. And also the increasing temperature of the generator during the HHO process is directly proportional to the distance between the plates of the generator.

By examining all the results observed it has proven that the most convenient and the efficient design methodology for HHO generator is the three electrodes method with minimum plate distance. The observations also proved that with rising temperature of the generator increases the current flow result in increasing the production of HHO. It is observed that the average amount of current the generator can handle in its most efficient condition is only 6 A in this configuration. So the designed solution in preventing the fact observed is shown in Fig. 12. The circuit introduced here is a Pulse Width Modulator (PWM) with current limiting in order to limit the amount of current to 6 A. The width of the pulse is controlled according to the feedback signal obtained from the voltage applied to the generator.

The proposed method can be used in a vehicle in order to increase the fuel efficiency of it. The outlet valve of the designed generator should connect to the gas intake of the combustion engine. In this approach the vehicle should be tested without the HHO generator and measure the fuel consumption for predetermined miles at a constant rate of speed as the initial step. In testing the vehicle with the HHO generator the oxygen sensor stored inside the exhaust pipe of the vehicle should adjust as required. If not, the emission of O_2 during the HHO combustion process may generate false readings from the oxygen sensor which causes in increasing the fuel consumption. In an ordinary vehicle, when exhaust O_2 percentage is high, oxygen sensor output voltage goes low. Similarly, when the percentage of O_2 is low the sensor will have a high voltage value. This type of oxygen sensors are widely used in modern vehicles. The block diagram for the proposed complete system is shown in Fig. 13.

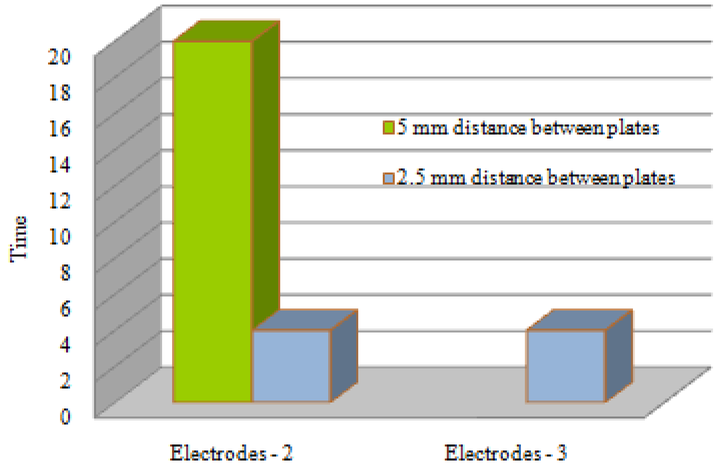


Fig. 10 Comparison of results in Table - 1 and Table – 2

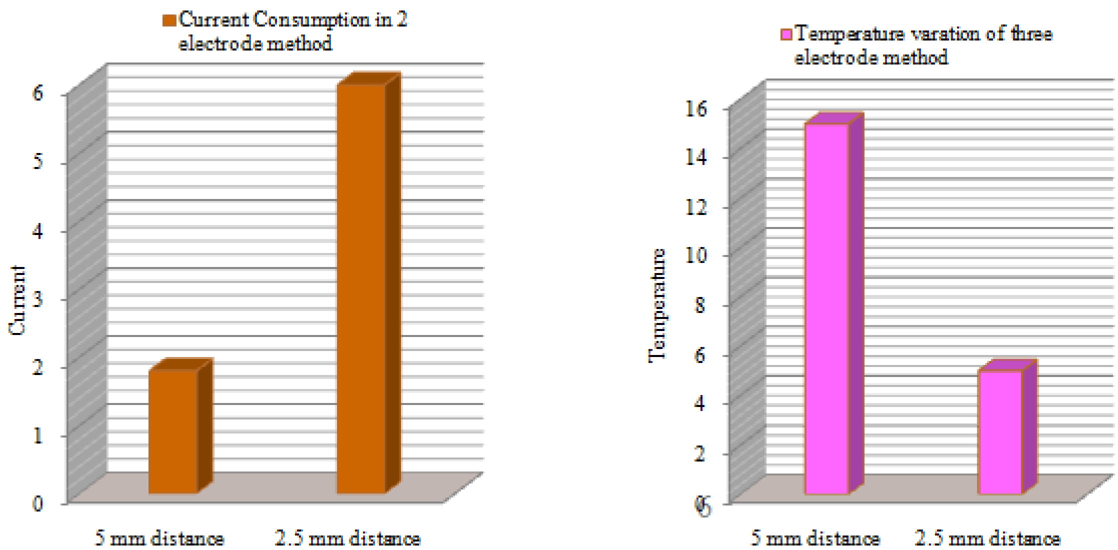


Fig. 11 (a) Maximum flow of current to generate 1 ℓ of HHO, (b) Representation of results in Table - 3

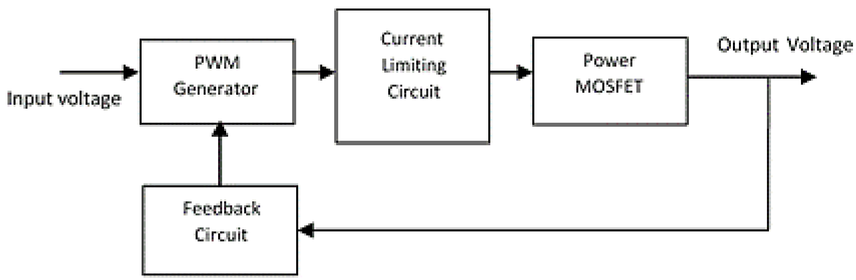


Fig. 12 Block diagram of the Electronic Circuit

The sensor keeps tracks on the O_2 emission compared to the percentage of O_2 in the atmosphere. When consider a scenario where the Oxygen in the exhaust system is higher than the atmospheric air, Oxygen sensor gives a low output voltage and vice versa. Also when the oxygen sensor outputs a high voltage means that the air/fuel ratio is lean, while it calls the air/fuel ratio is rich when the output voltage is low. When using HHO in Spark Ignition Engines, the emission gasses may have a greater percentage of Oxygen than in normal condition, i.e. using gasoline as fuel.. Hence, that the oxygen sensor should adjust according to the percentage of oxygen emission for the Spark Ignition System with the HHO system attached.

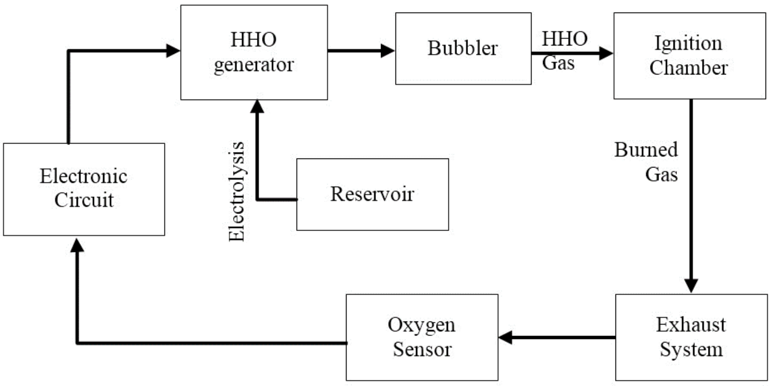


Fig. 13 Block diagram of the Complete System

CONCLUSION AND FUTURE WORK

In this research we have proposed a convenient and an efficient method to build up a HHO generator. According to the results observed the amount of HHO increases when the supply current is increased. . In addition increasing cell temperature also increases the production of HHO. To build an efficient HHO generator the distance between the plates, Catalyst used, material used and also the number of plates and electrodes used should thoroughly conceded.. In the proposed approach the amount of current flows through the generator increases with the temperature of the generator which makes the battery to drain fast. Taking this fact into consideration, future research will focus on limiting the current flow through the generator to obtain an optimal rate of HHO production.. Next step of this research is to connect the proposed HHO generator with an internal combustion engine, i.e. a spark ignition engine and measure the efficiency of the fuel in vehicle and also to measure the reduction of emission of air pollutants such as CO_2, CO, etc.

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