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Oxy-hydrogen fuel as supplement for gasoline vehicles using Dry cell Generator

Romit Nag, Smit Shrivastava

Abstract— Fuel deficiency is the biggest concern hovering the 21st century automobile manufacturers and developers. Gasoline run vehicles are abundant at present and this affects the reservoirs and results into its depletion. The consumption of this fuel is greater than it being replenished, thus research and development have been channelized towards discovering a possible replacement. Oxyhydrogen, being the byproduct of pure water is the supplementary fuel found to sustain with gasoline and improve performance of the engine system. Hydrogen gas being highly combustible can't be stored. Thus a system in which variable onboard production by varying current and usage of HHO gas has been devised. A controlled electrolysis of pure water in a compact hard polymer fabric material, using stainless steel plates as electrodes accomplishes the generation of HHO gas. Presence of HHO ions, traces of water and ionized oxygen particles, makes the combustion cleaner and faster. This also reduces hydrocarbon emission and keeps the engine cleaner due to better combustion cycle. This is a safe fuel, a cheaper alternative and the results compliment the current automobile production.

Index Terms— Dry Cell, Oxy-hydrogen, Electrolysis, Emission, Efficiency.

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1 Introduction

The automobile industry has been advancing at an exponential rate over the past decade. At the same rate, we're witnessing depletion of fuel reserves and increase in the emission of unburnt hydrocarbons. Technology has been used to improve design, increase engine power and also at making automobiles fuel efficient. Researches have been initialized to find alternatives - a cleaner and sustainable renewable source of energy such as electric cars, hybrid vehicles and solar powered vehicles. But these are either unreliable, costly or lack the infrastructure to support the technology.

The current requirement is to have a universally accepted sustainable fuel and as of now its gasoline. Every vehicle owner intends to own a car which looks good, provides good performance and high fuel efficiency, but despite recent advancements in technology, the balance hasn't been achieved. Due to the depletion of petroleum, transportation costs have increased, as they are solely dependent upon this fossil fuel. In India, the majority its population requires fuel and cost efficient vehicles - only CNG vehicles match this criterion, but even in those cases - maintenance increases and the engine takes a toll. The harmful byproduct of petroleum is pollution caused by CO, NOx and other unburnt hydrocarbons. Pollution leads to catastrophic environmental changes, global warming and other ecosystem imbalance. Thus there is an urgent need for conservation of petroleum while other options are worked upon.

Oxy-hydrogen is a promising supplement to gasoline, in which electrolyzed water is used to power combustion. The gas has a high calorific value which when injected with petrol supply, readily starts the combustion resulting into the reduction of 'brake specific fuel consumption' and increase in the 'break specific fuel efficiency'. Due to much cleaner combustion, the exhaust emission has lesser traces of NOx, CO, CO2 as well as HC. This is again reduced using the EGR which is omnipresent in every vehicle nowadays. Due to the reduced emission of exhaust gases in a HHO powered vehicle as compared to its petrol run variant, the EGR works more efficiently. The results therefore indicate increase in thermal efficiency, reduction in exhaust emission and cleaner engine manifold without any drastic change in the vehicle.

2 PRINCIPLE

2.1 Properties of HHO

As the name suggests, oxy-hydrogen gas is a mixture of hydrogen (H2) and oxygen (O2) gases bonded in a 2:1 ratio in which the "magnecules" of hydrogen (HH) are bonded with a lone oxygen (o) atom. This fuel has a high calorific value which when ignited produces 241.8KJ of energy (LHV) for every mole of H2 burned. The minimum energy required to ignite such a fuel requires only 20 micro joules, which at normal atmospheric pressure auto ignites at about 570 C. The necessary condition for the fuel to burn is to have the hydrogen content in between 4% and 95%. As water is being burned, there is no residual hydrocarbon

Oxy-hydrogen gas being highly diffusive and homogenous; is very advantageous in fuel to air mixture and due to low density, the safety in case of leakage is high. The production of this fuel is simple and can be controlled but difficult to store, thus being generated when required.

2.3 Electrolysis

Before Electrolytic cell development, preliminary calculations for flow rate determination were carried out using Faraday's first law of electrolysis. All calculation parameters were assumed to be at STP conditions

$$V=\frac{RxIxTxt}{Fxpxz} \quad (1)$$

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V= Volume of gas (L)
R= Ideal gas constant (L*atm/ (mol*K))
I= Current (A)
T=Temperature (K)
t= Time (s)
F= Faraday's constant (As/mol)
p= Ambient pressure (atm)
z= No. of excess electrons (Value of z is determined by considering cell half reactions)

The reaction taking place during electrolysis at the two electrodes is stated below.

Cathode (reduction):
$2\ H_2O(l) + 2e^- \rightarrow H_2(g) + 2\ OH^-(aq)$ (2)

Anode (oxidation):
$4\ OH^-(aq) \rightarrow O_2(g) + 2\ H_2O(l) + 4\ e^-$ (3)

Overall reaction:
$2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$ (4)

Considering STP conditions:

Volume of hydrogen $= \frac{0.0820577x1x273.15x3600}{96485x1x2} = 0.418151L$ (5)

Volume of oxygen $= \frac{0.0820577x1x273.15x3600}{96485x1x4} = 0.209075L$ (6)

Volume of HHO per ampere per cell = 0.627LPH/Amp per cell

Total oxy-hydrogen from the electrolytic cell = 0.627x No. of water compartments x Current

2.3 Wet cell vs Dry cell

A wet cell consists of electrodes dipped in a solution of electrolytes and conducting liquid where the power source when connected, starts the electrolysis. Due to the plates being dipped in the solution, current loss is experienced because of the electrodes being exposed. Due to the plates dipped in the conducting liquid, current jumps out of the edges of the plates by taking the less resistant path. Another disadvantage of the wet cell is that if the battery connections to the plates are loose, then it might lead to a catastrophic reaction and the setup may blow up.

Dry cell improves on these two disadvantages as the edges are not dipped in the electrolytic solution, so the current is forced to go through the plates. The plates are exposed for a minimal amount of time compared to the wet cell configuration. Hence, dry cell configuration is more efficient than wet cell in terms of current wastage.

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3 SETUP

3.1 Dry Cell

A 9 plate dry cell has been chosen for the HHO generator, which consists of 6 neutral plates and the anode and cathode in the arrangement such as +NNN-NNN+. The conducting liquid consisting of NaOH/KOH 10%w/w solution is stored in a tank with a flow rate valve attached to it.

The plates are made of stainless steel of grade 306 which is both non-corrosive and good conduction. Between each plate neoprene gaskets or PVC spacers are used to keep the spacing constant between plates. The dimensions of the plates are 143x92.20x1.65mm and the gasket thickness has been calculated to be 1.52mm. There is a water inlet valve and a gas outlet valve. HHO generation depends on various parameters such as surface area of the plate, spacing between two plates, electrolyte concentration.

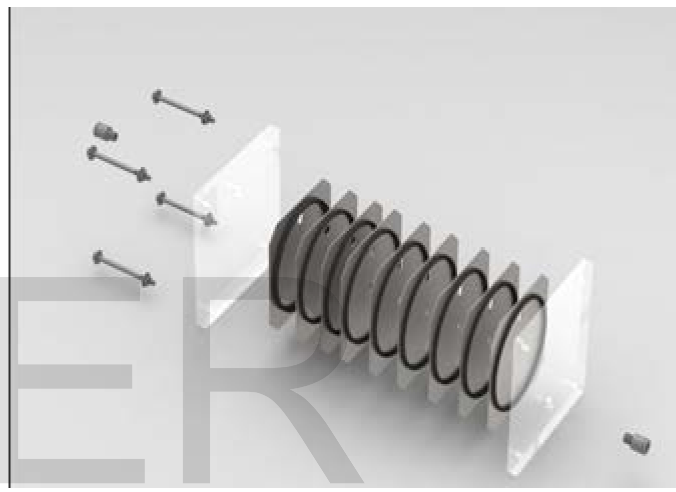


Fig1: Exploded view of the Dry cell

According to the Ohms Law, an increase in Resistance causes electron flow to be reduced. Electron flow is the amount of amperage the cell is drawing. The farther apart the plates are, the lesser amps the cell will draw through the water. The closer the plates are, the more amperage the cell will draw. Cell spacing and amperage are inversely proportional to each other. Addition of Electrolytes to pure water makes it conductive due to the presence of free ions. A decrease in resistance allows more current to flow; thus increasing the possibility of producing more HHO. A cell that has wide spacing can be made to produce just as much HHO as a cell with close spacing. The difference is going to be the amount of electrolytes added to the water. The cell with wide spacing will need larger amounts of electrolytes.

The temperature of the conducting fluid determines the amount of HHO gas being produced. Excessive heat relates to more amperage being drawn but overheating makes the system unstable. The heat occurs due to the movement of electrons and friction causes the temperature to increase during the current flow.

3.2 Pulse Width Modulator

A pulse width modulator is used to vary the voltage between 0V (low point) and 12V (high point). It controls the outgoing voltage by varying the duty cycle. Duty cycle is the percentage of time that the pulse is "on" compared to the time it is "off". It describes the width of the pulse over time, or the "pulse width" as a percentage. The duty cycle determines the amount of voltage that needs to be provided by the PWM. As the duty cycle goes up, and the voltage is on for a higher percentage of the time, current will flow for longer times. Thus by "modulating" the pulse width, the current flow changes immediately through our HHO cell. [ii]

3.3 Electronic Fuel Injection Enhancer (EFIE)

Electronic Fuel Injection Enhancer is used to limit the flow of gasoline in the engine manifold when the HHO setup initiates. The oxygen sensor determines the air to fuel ratio and intends to keep it at 14.7:1 but with introduction of HHO, the oxygen concentration increases, which increases the air to fuel ratio. When the ratio increases, the gasoline inflow increases too which makes the system unstable. The EFIE gives the ECU false signals to keep the fuel rich i.e. above 14.7:1, so that the ECU signals the fuel injector to send less gasoline and the HHO can be used at its potential. [iii]

4 WORKING

When the ignition starts, the DC switch gets switched on and closes the circuit to operate A 20 amps limit fuse is connected from the positive terminal of the 12V car battery. There are two separate wires from the EFIE, one from the ECU (Electronic Control Unit) and the other from the O2 sensor. The positive and negative terminal connections are attached to the PWM. The PWM gets a signal from the Arduino board which determines the duty cycle of the PWM. This is generated according to the crank sensor output, which detects the change in rpm. As the rpm increases the crank pulse changes proportionally. The Arduino is programmed in a manner in which the voltage pulse increases as the crank signal frequency increases. The PWM then completes the circuit with the HHO Dry cell.

The Dry cell stack combines plates of stainless steel grade 306 as 2 cathode, 1 anode and 6 neutral plates. A 10% solution w/w of NaOH or KOH is used as electrolytes in the cell. The water tank depends on the engine litre size.

Once the cell reaches operating temperatures between 140-158 F or 60-70 C, it consumes about 75 ml of water every hour of operation. So 1 liter of water should last about 13 hours of driving time for a 1 to 2 litres engine. A hose from the water tank is connected to the cell and another one to take out the HHO or Brown gas. As the ignition starts, the electrolysis is initiated at 1.23V and slowly reaches to its optimum voltage around 1.47V.

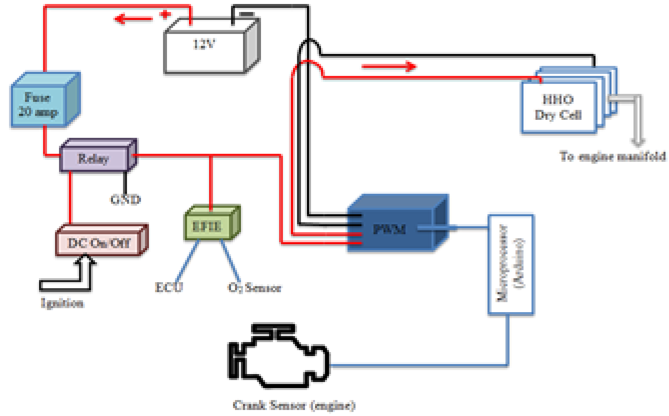


Fig2: System Connection

The amount of HHO being produced depends on the amount of amperage drawn from the dry cell. Amperage drawn depends majorly on two criteria: one being amount of electrolyte and the second one being temperature of the system. Cooler environment and setup draws less amperage and thus less production of HHO. The Fuse is kept inline so that the amperage doesn't cross 20 amps and make the system unstable.

The flashback arrester and the non-return valve are the safety devices used to avoid the backlash by the brown gas. This fuel is then channelized to the MAF (Mass Air Flow), using the gas flow rate valve, which helps the gas to defuse with the extra oxygen supply. The gasoline chamber has a pipe attached into the input manifold of the engine. The oxy-hydrogen being diffusive in nature readily gets mixed with gasoline and due to its high stoichiometric and calorific value; the ignition temperature is suitable for the mixture.

When this mixture (HHO + Gasoline) gets injected through the inlet valve, the sparkplug ignites the fuel and a much cleaner and faster combustion is recorded. This results into the increase in speed even after increasing the load gradually. Due to the fuel having high concentration of oxygen and traces of water, the fuel burns faster and the carbon deposit also reduces.[iii,iv].

5 CALCULATIONS

$$Z = \frac{I * Vp}{Pg * A * Pn}$$

Z=Target spacing between the plates
I=Target amperage per cell
Vp =Voltage potential
Pg=Target number of plate gaps
A=Total exposed surface area of the plate
Pn=Target number of plates used per cell

$$Z = \frac{5 * 13}{8 * 9593.52 * 9} = 1.52 \text{ mm}$$

Given:
I=5 Amps
Vp=13 volts
Pg=8
Pn=9
A= 9593.52mm²

6 TESTING AND RESULTS

The improvement in the performance and emissions are significant, as expected, the engine now using leaner fuel, Saves fuel and the combustion efficiency also increases. HHO gas significantly reduces the presence of carbon monoxide in the exhaust. It has been shown that introducing HHO gas to the combustion enhances the combustion efficiency and enhancement in thermal efficiency and specific fuel consumption will be evident.

Hydrogen and oxygen exist as tiny independent clusters of no more than two atoms per combustible unit. Comparatively, a gasoline droplet consists of many thousands of large hydrocarbon molecules. This diatomic configuration of HHO gas (H2, O2) results in efficient combustion because the hydrogen and oxygen atoms interact directly without any ignition propagation delays due to surface travel time of the reaction. On ignition, its flame front flashes through the cylinder at a much higher velocity than in ordinary gasoline/air combustion. The heat and pressure wave HHO generates crushes and fragments the gasoline droplets exposing fuel from their interior to oxygen and the combustion reaction. This effectively enriches the air/fuel ratio since more fuel is now available to burn. Simultaneously, the HHO flame front ignites the crushed fragments thereby releasing more of their energy, more.

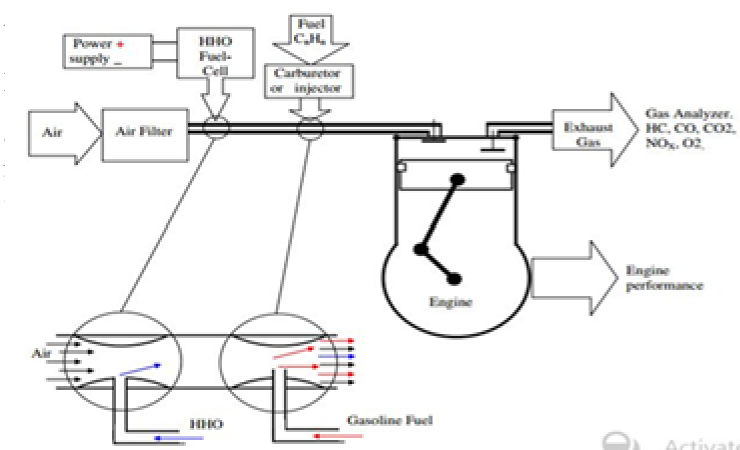
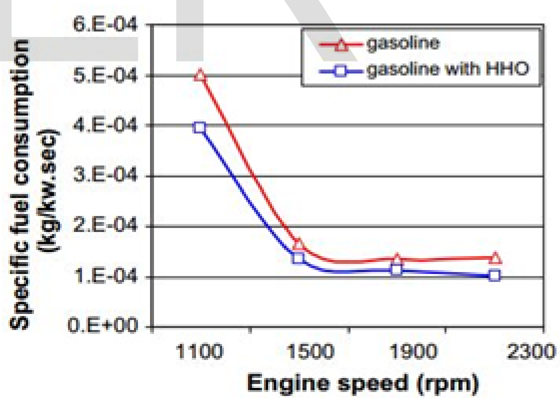


Fig 3: Schematic Experimental Setup.

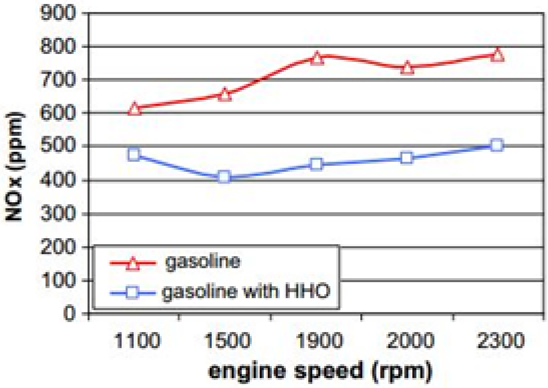
High NOX emission is usually noticed with highly heated and compressed air that has nitrogen in it. Adding HHO to gasoline increases the octane rating. This fact causes the gasoline to ignite before TDC (Top Dead Center, the point where the piston is at the highest point of its motion), making it less efficient because the explosion of gas fumes pushes the piston down and out of sequence (it is too early so it goes a bit in reverse) and therefore the 'pinging' noise and less power from regular gasoline. Brown's gas or water vapor causes regular low-grade fuel to ignite more slowly, making it perform like a high octane gasoline. A higher octane rating means stronger horse power due to combustion occurring much closer to TDC, where it has a chance to turn into mechanical torque (rotary push) the right way and without pinging. [v,vi]

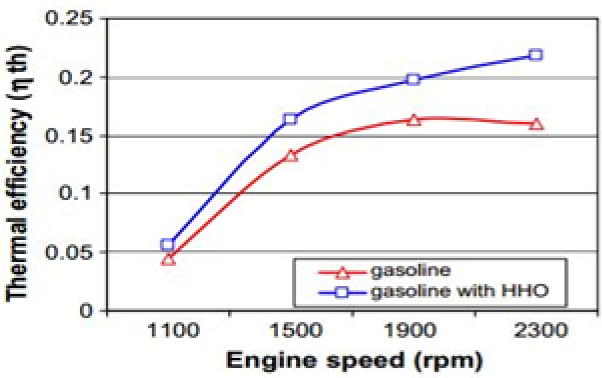
Each piston transfers more energy during its combustion cycle, so combustion becomes more efficient as well as. More efficient combustion translates to less fuel being consumed. The variation of oxygen concentration and carbon dioxide concentration in the exhaust with engine speed is presented in and respectively. One can notice that the result shows two segments. The first is up to 1900 rpm engine speed, oxygen presence increased by about 20% when HHO gas has been introduced to the system, whereas carbon dioxide is reduced by 40%. The second segment shows no significant difference in either oxygen or carbon dioxide concentrations. This is related to the time available to combustion reactions to take place; higher engine speed is directly related to shorter combustion time.

HC's are usually the worst problem for vehicle engines. HC which refers to hydrocarbons, are simply another term for unburned fuel that makes way through the engine and out the exhaust. One can notice that HC concentration in the exhaust is reversely related to the engine speed. This is due to an increase in turbulence intensity mixing process of burnt and unburnt gases which increases oxidation rate of HC. Also a reduction in HC concentration in the exhaust as a result of introducing HHO is noticed. [vii,viii]



The emission test showed the positive results due to increase in efficiency of the combustion, the burning of the fuel was more efficient and thus lesser unburnt hydrocarbons (Figure2) as well as lower percentages of CO gas (Figure 2). In the long run of testing the increase in fuel efficiency also showed increase of about 18 to 20 percent.





7 CONCLUSIONS

☐ HHO cell may be integrated easily with existing engine systems.

☐ The combustion efficiency has been enhanced when HHO gas has been introduced to the air/fuel mixture, consequently reducing fuel consumption.

☐ The brake thermal efficiency of the engine has increased due to HHO addition.

☐ When HHO is introduced to the system, the average concentration of carbon monoxide has been reduced to almost 20% of the case where air/fuel mixture was used (no HHO).[ix]

☐ The NOX average concentration has been reduced to about 54% of the case where HHO was not introduced.[x]

☐ A decrease in HC emissions was observed.

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