ISSN 0973 – 6921 ; E – ISSN 2319 – 5983 *J. Environ. Res. Develop.*
Journal of Environmental Research And Development Vol. 12 No. 01, July-September 2017

FUEL CONSUMPTION AND EXHAUST EMISSION CONTROL IN INTERNAL COMBUSTION ENGINES BY USING HYDROXY GAS (HHO) : A REVIEW

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Received September 12, 2016 *Accepted June 14, 2017*

ABSTRACT

The fuel consumption and emission pollution associated with oil combustion is gaining, an increasing in the world. Recently, Hydroxy gas (HHO gas) has been introduced as an alternative clean source of energy. The Hydroxy gas (HHO) was produced by the electrolysis process of different electrolytes with various electrodes in leak proof hydrogen generator. The design of new device attached to the engine, to integrate an HHO production system with the gasoline engine. The device is compact and installed in engine compartment. The results show that a mixture of HHO, air and gasoline cause a reduction in the concentration of emission pollutant constituents and an enhancement in engine efficiency. The emission tests have been done with varying the engine speed. The results show that nitrogen monoxide (NO) and nitrogen oxides (NO_x) have been reduced when a mixture of HHO, air and fuel was used. Moreover, the carbon monoxide concentration has been reduced. Also a reduction in fuel consumption has been noticed and it ranges between 20% and 30%.

Key Words : Internal combustion engine(SI engine),4-stroke Gasoline Engine, Fuel, Brown's gas (HHO), Fuel cell (FC)

INTRODUCTION

Global warming is considered one of the major problem, the scientific community has to face. Many theories refer to the increase of exhaust gases concentration in the atmosphere as one of the major causes of the global warming[1]. Industrial plants and automobiles are the major source of the exhaust gases. Since they utilize the power associated with oil combustion as energy source. Emissions are simply the exhaust or leftovers of combustion coming out of an engine. An emissions test is normally donewith a probe placed into the exhaust stream. Every road going vehicle has certain clean requirements that it is required to meet. The emission sampler, which is known as gas analyzers, measures five types of gases. These gases are HC, NOx, O_2, CO, and CO_2[2]. HC which refers to hydrocarbons, are simply another term for unburned fuel that makes it way through the engine and out the exhaust. Smog intensity is proportional to the amount ofHC's in the exhaust[3]. HC's is also considered hazardous when inhaled. NOx refers to oxides of Nitrogen. High NOx emission is usually noticed with highly heated and compressed air that has nitrogen in it[2,4]. NOx is another bad emission to breath at high levels. O_2 which is unburned oxygen in the exhaust is also measured. Although O_2 is obviously not bad, it is tested to better understand the combustion characteristics[4]. Knowing the percentage of oxygen in the exhaust one may estimate the air/fuel ratio of the engine as it runs. CO and CO_2 refer to carbon monoxide and carbon dioxide respectively. Odorless CO causes headaches and eventually death by hold up O_2 from the human body, if it exists in high quantities. Carbon dioxide (CO_2) is present in the air in large amounts contribute to green house effect and consequently global warming. HC's are usually the worst problem for vehicle engines[3]. Many things can produce high HC's such as advanced timing, and bad catalytic converter. NOx is generally worse on higher compression engines. All engines produce NOx but the use of Exhaust Gas Recirculation Valve (EGR) valves will cool and slow down

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the combustion rate of the engine. This considerably lowers NOx values[4]. CO has to do with the efficiency of the combustion in the engine and also is highly affected by the fuel to air ratio of the engine. CO_2 is also an indicator of the engines set up. The HC's and NOx are by far the largest problem areas[2,4]. A shift in scientist's interests, recently observed, toward lower fuel consumption and emission engines take place. This encourages researchers to seek for alternative solutions to be used in engines without the need for a dramatic change in the vehicle design. Among those using HHO as an alternative fuel which enhances the engine efficiency and runs with almost zero pollution effect[5]. Water (H_2O) is composed of two parts hydrogen and one part oxygen (HHO). The Water Gas Green Machines use electricity to separate the hydrogen and oxygen found in water. The separated hydrogen and oxygen are mixed with gasoline and outside air[6]. The "mixed" gas is then drawn into the engine using vacuum pressure, where it is mixed with gasoline and ignited by the spark plugs.

This gas differs substantially from ordinary hydrogen gas[7]. It is 3.8 times more power than gasoline alone. This process will make about 1,866 quarts of hydrogen/oxygen gas from 1 quart of water. Mixing this gas is a very simple, effective and safe process[8]. Without the need for pressurized tanks, it makes previous concerns about hydrogen safety all but irrelevant[9]. The hydrogen and oxygen in Water (Brown's) Gas are in a simplified monatomic (H_2O) form which converts to energy more efficiently than the diatomic (H_4O_2) hydrogen and oxygen found in tap water. Ali Can Yilmaz et al. studied the effect of HHO gas addition on compression ignition engines[10]. His results showed significant enhancements in the engine performance due to the presence of HHO.The main objective of the present study is to introduce some of the hydrogen advantages and maintain the original specifications of the engine. This may be attained by introducing HHO cell to the fuel supplying system. So, the fuel becomes a mixture of gasoline and HHO gas. Our kits use a vacuum driven bubbler - first used on fighter planes in WWII - to draw Brown's Gas and water vapor into the engine manifold where it combines with the hydrocarbon (gasoline) fuel. The amount of Brown's Gas and vapor being drawn into the engine manifold is very small - less than 0.25% - but its effect on the power output of the gasoline is dramatic.

Theory of water electrolysis

Since the electrolysis phenomenon was discovered by Troostwijk and Diemann in 1789[11].The electrolysis of water is considered a well known principle to produce oxygen and hydrogen gas. In **Fig.1** a schematic of an electro-chemical cell is presented. The core of an electrolysis unit is an electrochemical cell, which is filled with pure water and has two electrodes connected with an external power supply. At a certain voltage, which is called critical voltage, between both electrodes, the electrodes start to produce hydrogen gas at the negatively biased electrode and oxygen gas at the positively biased electrode[12]. The amount of gases produced per unit time is directly related to the current that passes through the electrochemical cell. In water, there is always a certain percentage found as ionic species; H+ and OH- represented by the equilibrium equation.

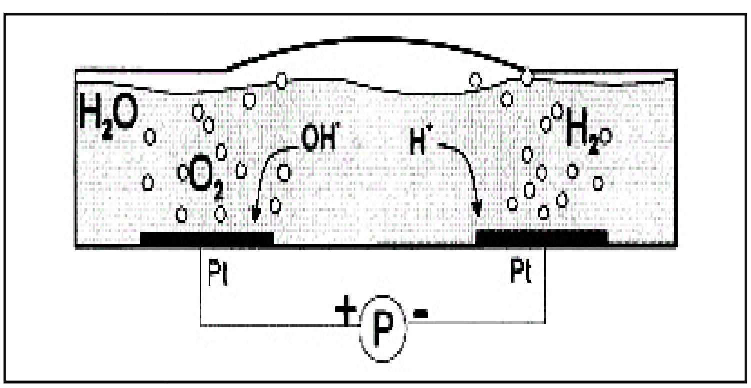

Fig. 1 : Sketch of an electrochemical cell

H_2O (l)↔H+ (aq) + OH- (aq)

Oxygen and hydrogen gas can be generated at noble metal electrodes by the electrolysis of water:

+ve electrode (anode):

4OH- ↔ $2H_2O + O_2$ + 4e- (2a)

-ve electrode (cathode):

2H+ (aq) + 2e- ↔ H_2 (g)

Principle of the alkaline water electrolysis

The decomposition of water into hydrogen and oxygen can be obtained by passing a direct electric current (DC) between two electrodes separated by a membrane and containing an aqueous electrolyte with good ionic cond-uctivity. The electrodes are immersed in an alkaline aqueous solution with weight conc-entration (wt%) and therefore they must be corrosion resistant, have good electrical conductivity and catalytic properties, allowing better electrochemical transfer[13]. The memb-rane or diaphragm separating the anode and cathode compartments is made generally with Asbestos or nickel oxide (NiO) and must have a low electrical resistance, good mechanical behavior and low gas crossover. A complete description of alkaline electrolysis requests a multi-physics approach including interc-onnecting domains such as thermodynamic, electrochemical, conceptual materials and two-phase fluid flow. For this purpose, a theoretical basis including new developments is necessary for a better comprehension of the influent effect and the implementation of the new model. The model **(Fig. 2)** describes the beha-vior of the electrolyzer and its performance depends on fixed parameters (geometry, surface mater-ials, pressure) and other variables parameters (concentration, electrical conductivity, bubb-ling).

Alkaline electrolysis has become a well matured technology for hydrogen production up to the megawatt range, and constitutes the most extended electrolytic technology at a commercial level worldwide[14]. A direct current (DC) is applied to maintain the electricity bala-nce and electrons flow from the negative terminal of the DC source to the cathode at which the electrons are consumed by hydrogen ions (protons) to form hydrogen. In keeping the electrical charge (and valence) in balance, hydroxide ions (anions) transfer through the electrolyte solution to anode, at which the hydroxide ions giveaway electrons and these electrons return to the positive terminalof the DC source. In order to enhance the conduc-tivity of thesolution, electrolytes which gener-ally consist of ions with highmobility are applied in the electrolyzer[15]. Potassium hydr-oxide ismost commonly used in water electrolysis, avoiding the hugecorrosion loss caused by acid electrolytes[16] Plates of fuel cell is made stainless steel-grade 316-L are used as the cell plates. The cell plates have an anode and cathode. Both of them made of the same materials. As a result of experience stainless steel grade 316-L is essential for the fuel cell[8]. The electric current entered the anode and then passes to the cathode through the electrolyte. The cell plates are arranged inside a Plexiglas box supplied by the required fittings and piping.

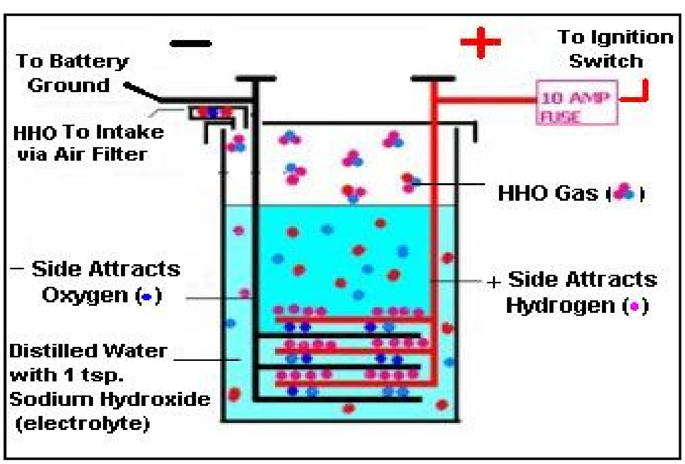

Fig. 2 : Alkaline water electolysis

In acidic or basic water, the reactions which occur at the electrode interface are slightly different. In water electrolysis there are no side reactions that could yield undesired bypr-oducts, therefore the net balance is[2]:

$2H_2O \longrightarrow (4e\text{-}) \longrightarrow O_2 + 2H_2$

The fuel cell (FC) electrodes immersed in a liquid alkaline electrolyte consisting of a catalytic0.1% of the solution.Researchon FC is currently going on with main target is to enhance the fuelcell performance and/or reduce the fuel size[17]. The fuel cellused in this rese-arch is basically an electrolyte cell which decomposes distilled water (H_2O) into HHO. Heat is generated due to this electrolysis process which accelerates the decomposing of H_2O into HHO and assure control of the heat generation. HHO gas generated, in electrol-ysisprocess, due to the separation to water molecules H–HO. It has high potential energy, the caloric value of HHO gas is three times that of gasoline[18].

Three major issues are normally associated with alkaline electrolyzers, low partial load range, limited current density and low operating pressure. First, the diaphragm does not completely prevent the product gases from cross-diffusing through it. The diffusion of oxygen into the cathode chamber reduces the efficiency of the electrolyzer, since oxygen will be catalyzed back to water with the hydrogen present on the cathode side. Additionally, extensive mixing (particularly hydrogen diffusion to the oxygen evolution chamber) also occurs and must be avoided to preserve the efficiency, as well as safety. This is particularly severe at a low load (<40%) where the oxygen production rate decreases, thus drastically increasing the hyd-rogen concentration to unwanted and dangerous levels (lower explosion limit >4 mol% H2)[19]. The second drawback for alkaline electrolyzer is the low maximum achievable current density, due to the high ohmiclosses across the liquid electrolyte and diaphragm. The third problem, also attributed to the liquid elect-rolyte, is the inability to operate at high pressure, which makes for a bulky stack design configuration.

Hydrogen and CNG

In the Norwegian University of Science and Technology, an experimental study was made recently, adapting a spark ignition engine, originally fueled with natural gas (NG), to be fueled with mixtures NG/hydrogen[19]. The engine was a three cylinder of 2.7 l and a compression ratio of 11:1. It was observed that adding hydrogen to NG, hydrocarbon emissi-ons are well reduced. When air excess ratio λ is in the range of 1.6–1.8, hydrocarbon emissions in air/NG rise in an important amount, while for hydrogen/NG mixtures, this rise occurs in the range of 1.8–2.0. This means that hydrogen allows working with leaner mixtures, without having sudden rises of unburned hydrocarbon (UHC) emissions. Emissions of nitric oxides with both types of mixtures were observed. Presence of hydrogen leads to greater flame velocities and temperatures, increasing the emissions of nitric oxides. However, when excess air ratio is over than 1.5, emissions below 5 ppm can be obtained, representing an advantage when working with lean mixtures of hydrogen. With values of l over 1.5 in hydrogen/NG mixtures, it can be observed efficiencies over 30% and power outputs over 20 kW, both values greater than those of NG mixtures.

Engineering faculty of the Eciyes

University, in Turkey, a technical review about hydrogen/CNG mixtures in spark ignition internal combustion engines at different concentrations and spark timings were made[20]. Akansu et al. reported a maximum efficiency at 30^{o}CA BTDC, being of almost 50%, with an equivalence ratio ϕ of 0.8 and 40% Vol. of hydrogen in the mixture. In terms of exhaust gases, emissions of nitric oxides and UHC were reported in two cases: with catalytic converter and without it. For the nitric oxides emissions, the amounts emitted with NG and hydrogen/NG mixtures are comparable in some ignition timings when the catalytic converter technique is applied; however, it is shown that at 22 ^{o}CA BTDC, the production of this emiss-ions reduces considerably with the hydro-gen/NG emissions. For UHC, the levels of the hydrogen/NG mixtures are always below of that of NG mixtures, due to the reduction of consumption of methane.

Hydrogen and diesel

In terms of compression ignition engines, to work with hydrogen as a fuel inthe Diesel cycle, such as the case of the Anna University, in India[21]. In the paper published by the authors, they reported the use of a single cylinder compression ignition engine, with direct injection. Diesel fuel works as a source of ignition. Hydrogen supply takes place in two ways until reach the1500 rpm, with a power output of 3.78 kW: by carburetion and timing port injection (TPI). It can be observed that the major efficiency (27.5%) is reached with the diesel/hydrogen mixture, using TPI technique. In terms of emissions, nitric oxides have an important role when hydrogen is introduced inthe mixture, because authors observed higher levels at 2500 rpm, with a brake power output of 4 kW, while emissions of UHC reduced to approximately 25% of the air/diesel mixtures emissions. Carbon mono-xide emissions also were reduced in the same percentage of the UHC.

Masood et al.[22,23] made experimental and computational work on a hydrogen diesel dual fuel engine, with hydrogen presence from 10 to 80% Vol. It was noticed that with the increase of hydrogen load the pressure increases at high compression ratios due to the high flamm-ability and rate of combustion of hydrogen. Moreover, hydrogen hasa major flame velocity at stoichiometric conditions, which makes the engine getting closer to the thermodynamically ideal engine.

Hydrogen and air

In the Madras Institute of Technology, a comparison study between gasoline and hydr-ogen as fuels was made[24]. For this purpose, a single cylinder spark ignition engine was adapted to be fueled with hydrogen by injection in the intake manifold. The results of UHC emissions showed that, using hydrogen as a fuel, the levels were near zero, while with gasoline it would maintain over the 2500 rpm, at different requirements of power output. The specific fuel consumption, working with hydrogen, is less than the half that of gasoline, due to the low energy density of hydrogen.[25,26] For the case of nitric oxides emissions, it was reported higher levels in hydrogen combustion. The emissions of the first mixture were about 8000 ppm at an equivalence ratio of 0.85, while for gasoline it was reported 2000 ppm at an equivalence ratio of 1.03, approximately. The minimum ignition energy and the wide range of flammability of hydrogen allow the presence of combustion at lower equivalence ratios than those with gasoline, and it can obtain a higher power at specific equivalence ratios.[27,28] The higher power output of the engine, running with hydrogen, was about 80% of the power reached with gasoline. Volumetric efficiency was plotted versus power output and thermal efficiency versus equivalence ratio. In the first case, a higher volumetric efficiency, compared with that of gasoline, with a power output between 2 and 7 kW, was observed. In the case of thermal efficiency, it was reached a maximum of about 27%, at different speeds, over that with gasoline which is about 25%.

RESULTS AND DISCUSSION

Engine torque

An average of 19.1% increment in engine torque is obtained with using HHO system compared to pure diesel operation. The incr-ease in power is due to oxygen concen-tration of hydroxy gas and better mixing of hydroxy with air and fuel that yield enhanced combustion.

SFC

An average gain of 14% is achieved onSFC by using hydroxyl system. Brake thermal efficiency is usually used to symbolize the engine economic performance. The impro-vement in engine brake thermal efficiency for the hydroxy enriched CIengine is more evidently seen at high speed conditions. The reduction in SFC is due to uniform mixing of hydroxy with air(high diffusivity of hydroxy) as well as oxygen index of hydroxy gas which assists gasoline during combustion process and yields better combustion.

HC emissions

An average reduction of 5% at HC emission is achieved above the engine speed of 1750 rpm. Short quenching distance and wide flamm-ability range of hydrogen yield engine to expel less HC emissions.

CO emissions

An average reduction of 13.5% is gained at CO emissions at mid and higher engine speeds (_1750 rpm). Absence of carbon in hydroxy gas is a major reason for CO reduction.

CONCLUSION

There was observed that the hydrocarbon emissions reduced when air excess ratio λ is in the range of 1.6–1.8 by the combination of hydrogen and Natural Gas (NG), in case of hydrogen gas leads,the flame temperatures and velocities increase the nitric oxides emissions about 1.5 times. When hydrogen gas use as a fuel in the Diesel cycle, there was diesel fuel works as an ignitionsource. It can be observed that the efficiency of engine reached 27.5% with the diesel/hydrogen mixture, using TPI technique. In this technique nitric-oxide and monoxide emissionsof UHC reduced to approximately 25% at 2500 rpm.Gasoline and hydrogen fuel mixture was also increased the nitric oxides emissions at higher levels.

Scope for further research

i). To reduce globule warming in the world, which are produced by exhaust emission from the internal combustion engine.
ii). To increase the production rate of hydroxy gas (HHO) by variation of current, voltage and surface area of electrode.
iii). To reduce the equipment setup cost and make fuel consumption economy.
iv). Increase the performance of the engine such as thermal efficiency, mechanical efficiency and torque.

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