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An Experimental Assessment of Performance and Exhaust Emission Characteristics by addition of Hydroxy (HHO) gas in Twin cylinder C.I. Engine

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ABSTRACT: The purpose of this research work is to study the effectiveness of hydroxy (HHO) gas as an additive to a conventional four stroke, twin cylinder, direct injection (DI) compression ignition (CI) engine without any modification and need of a storage tank. Here HHO gas was produced by the electrolysis process of three different electrolytes such as (KOH(aq), NaOH(aq), K_2CO_3(aq)) with the electrode material built up of mixed metal oxide (MMO) coated titanium plates in a dry cell type HHO gas kit. In this experimental investigation, the HHO gas produced at a steady flow rate of 0.45 lpm was mixed with the inlet air after the air filter at the inlet manifold. The performance and exhaust emission tests were conducted at a constant engine speed of 1500 rpm, resulting into increase in brake thermal efficiency ($\eta_{B.T.}$) and volumetric efficiency ($\eta_{Vol.}$), whereas there is a drop in the brake specific fuel consumption (BSFC), indicated mean effective pressure (IMEP) of the diesel engine. There was also some decline in the curves of carbon monoxide (CO), unburned hydrocarbon (UBHC) and nitrogen monoxide (NO) emissions. When comparing among these three different electrolytes which were added into the water to diminish hydrogen and oxygen bonds, to form HHO gas, KOH(aq) was specified as the most appropriate electrolyte, as it gave better performance and emission results.

KEYWORDS: Hydroxy gas, Electrolysis, Compression Ignition Engine, Performance, Exhaust Emission.

I. INTRODUCTION

As we know that sources of petroleum fuels are limited and with the present state of its usage; it will one day get depleted in near future, also their concentrations are limited to some of the nations therefore their dominance will ever exist. Moreover, as a result of global warming, coastal areas are getting submerged and burning of petroleum fuel will put in green house gases. As the rate of petroleum products are increasing and are too expensive to most of the citizens in the developing countries [12]. The major pollutants from the conventional hydrocarbon fuels are unburned/partially burned hydrocarbon (UBHC), CO, oxides of nitrogen (NOx), smoke and particulate matter.[2,5] It is very important to reduce exhaust emissions and to improve thermal efficiency. The higher thermal efficiency of diesel engines certainly has advantages for conserving energy and also solving the greenhouse problem[1,6].

How significantly the researchers aspire to compensate with an alternative fuel for our means of transport, but the outcome is that we are still lagging behind in the technical aspect compared to petroleum fuels [7]. So not to compete with petroleum fuels but to facilitate petroleum fuels to exist longer life in turn help to survive this ever demanding automobile industry [9,10]. The approach 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 technology, it is difficult to achieve the golden mean between them. So with the intention to conserve petroleum fuels for future and to get rid of the above mentioned limitations, there is a need of alternative and innovative fuel [12].

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Electrolysis of water can provide us HHO gas which is an enriched mixture of hydrogen and oxygen bonded together molecularly and magnetically, can be used as an additive to the conventional fuels for any internal combustion engine [3]. This gas will combust in the combustion chamber when brought to its auto-ignition temperature. For a stoichiometric mixture at normal atmospheric pressure, auto-ignition of HHO gas occurs at about 570°C (1065°F) and the heating value as 241.8 KJ [8,11]. At NTP, HHO 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°C is achieved with a pure stoichiometric mixture, about 700°C hotter than a hydrogen flame in air [11]. HHO 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 leakage occurs it can disperse at rapid rate. HHO gas is very low in density. This results in a storage problem when used in an IC engine [12]. It is to be noted that by several researches it is found out that one litre of water produces about 1866 litres of HHO gas. When this gas is ignited, the volume is reduced to the original one litre of water [4].

As the environment is experiencing tremendous problem at the moment, and one of the most serious of these is that we are losing our oxygen. The oxygen content of the air is becoming low that it threatens our very existence in some areas. The normal oxygen content of air is 21% by volume but in some places it is only a very small fraction of that. If it reaches 5% people will begin to die. Eventually if something is not done this low oxygen situation will effect each and every one of us. HHO gas created through an electrolytic process actually may contribute oxygen to the air supply, rather than leaving it the same (as with fuel and pure Hydrogen) or consuming it with fossil fuels. It is for this reason that we feel it will be the future technology of choice for running our vehicles. In this research work, the generation of HHO gas is discussed and its influence on the performance and exhaust emission characteristics for a four stroke, twin cylinder, direct injection CI engine is studied.

II. MATERIALS AND METHODS

Here HHO gas was produced by the electrolysis process using three different electrolytes such as (KOH(aq), NaOH(aq), K_2CO_3(aq)) at a steady flow rate of 0.45 lpm was mixed with the inlet air after the air filter at the inlet manifold. The electrode material built up of mixed metal oxide (MMO) coated titanium plates in a dry cell type HHO gas kit. The figure 1 shown below shows the circuit diagram of the HHO gas system used for this experiment.

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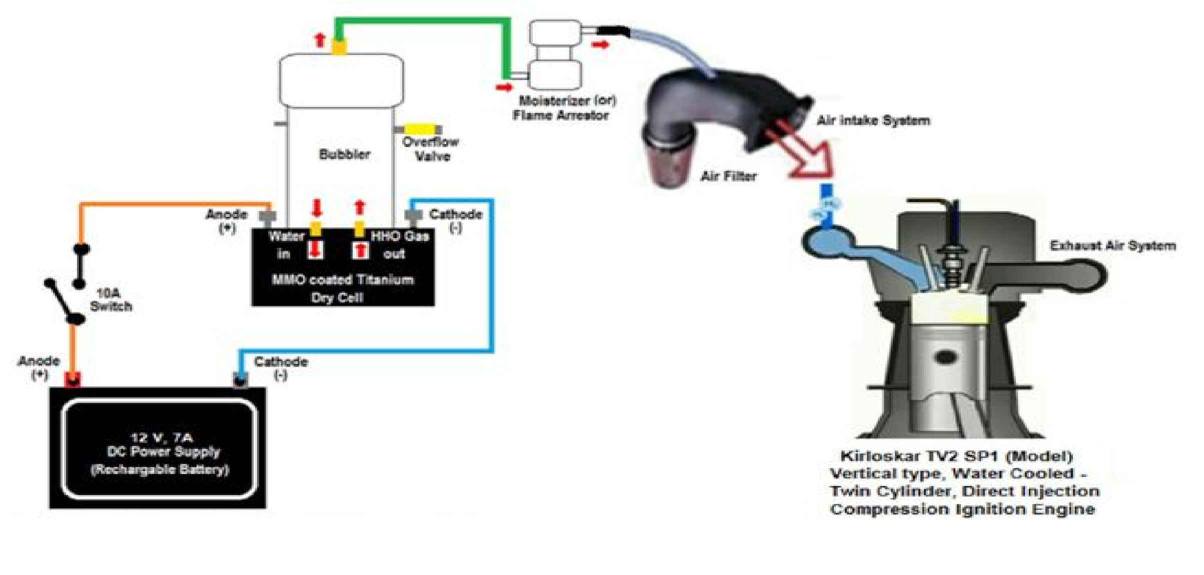

Figure 1: Circuit Diagram of the HHO gas system used for this Experiment

Here inside the dry cell unit, the electrode material built up of mixed metal oxide (MMO) coated titanium plates, are found in three stacks, which contain two positively charged plates and two negatively charged plates. The distance between two power plates are maintained as 24.5mm, whereas there are four neutral plates in between each power plate. Each plate made up of mixed metal oxide (MMO) coated titanium was separated from the next consecutive plate by a 2.5mm thick rubber gasket. The dry cell unit, was combined together by using stainless steel 316L bolts and nuts. The electrolytic aqueous solution was made to pass through these three stack through drilled holes. The surface area of contact of this electrolytic aqueous solution with the mixed metal oxide (MMO) coated titanium plates resulted in the production of HHO gas when external power supply was given to the electrodes. The reactions which occur at the cathode and anode are given below. In the negatively charged cathode, reduction reactions take place, with electrons (e^-) from the cathode being given to hydrogen cations to form hydrogen gas.

Cathode (Reduction)Reaction: $$2H^+ (aq) + 2e^- \longrightarrow H_2 (g) \quad (1)$$

At the positively charged anode, an oxidation reaction occurs, generating oxygen gas and giving electrons to the cathode to complete the circuit.

Anode (Oxidation) Reaction: $$2H_2O(l) \longrightarrow O_2(g) + 4H^+ (aq) + 4e^- \quad (2)$$

The same overall decomposition of water into oxygen and hydrogen is given in the reaction below.

Overall Reaction: $$2H_2O(l) \longrightarrow 2H_2 (g) + O_2 (g) \quad (3)$$

Here the number of hydrogen molecules produced is twice the number of oxygen molecules. At equal temperature and pressure for both gases, the produced hydrogen gas has therefore twice the volume of the produced oxygen gas. The

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number of electrons pushed through the water is twice the number of generated hydrogen molecules and four times the number of generated oxygen molecules.

A 12V, 7A battery was used as a external power source for this experiment. The anode i.e. the positive of the battery was connected to the anode terminal of the dry cell via an electronic switch of 10A for better control, whereas the cathode i.e. the negative to the cathode terminal of the dry cell. The electrode material for this experimental HHO gas kit is made up of mixed metal oxide (MMO) coated titanium plates which were relatively giving better reliability and durability than the titanium plates and that of the 316L stainless steel plates. The special feature of this HHO gas kit when compared to existing ones are it has the same reservoir tank acting as the bubbler unit to prevent back fire. Also the bubbler is attached to the dry cell unit to avoid the leakage of electrolyte and HHO gas. In the pre-installation testing the leak check was done as well as its performance to produce the HHO gas was also test in terms of litres per minute (lpm). Once the HHO gas leaves the bubbler which is made up of hard PVC material it have to pass through a moisturizer cum flame arrestor unit through a 0.5 mm diameter pipe. The moisturizer cum flame arrestor unit, helps to remove the moisture content is removed from the HHO gas and then this dry HHO gas is let inside the air intake manifold of the twin cylinder engine again through a 0.5 mm diameter pipe. Here the HHO gas mixes with the air and enriches the air with Hydrogen gas, this results in a Hydrogen rich air at the inlet of the combustion chamber. When diesel fuel is directly injected it takes very less time for mixing with this HHO and air mixture. Thus resulting in complete combustion of the hydrocarbon fuel, thereby lowering emission and increasing fuel efficiency.

III.EXPERIMENTAL SETUP AND PROCEDURE

The research work was conducted in a four stroke, twin cylinder, DI- CI engine without any modification and without need for storage tanks. The HHO gas produced at a steady flow rate of 0.45 lpm was mixed with the inlet air after the air filter at the inlet manifold. The diesel engine specification are given in Table 1. The various apparatus and instruments used for performance and exhaust emission testing are AVL five gas analyser, multimeter, stopwatch etc. The AVL five gas analyser was used to measure the concentrations of HC, CO, CO_2, O_2 and NO content in the exhaust gas coming out of the engine. The multimeter was used to measure the voltage and current of the external power source and also that of the HHO gas kit while production of HHO gas. Table 2 shows the data collected for current required from the power source for different electrolyte per litre (EPL) for 500ml of electrolytic solution. Table 3 shows the data for HHO Gas Generation (in lpm

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Table 1: Experimental Engine Specification

Engine Type	:	Vertical, Twin Cylinder, Water Cooled, Four Stroke Cycle, Compression Ignition Engine
Make/Model	:	Kirloskar/TV2 SP1
Installed at	:	Thermal Engg. Lab., VEC, Chennai
Fuel Used	:	Diesel
Power Output	:	7.4 KW
Power Rating	:	10 bhp
Rated Speed	:	1500 rpm
Cubic Capacity	:	1.322 Lts
Bore Diameter	:	80 mm
Stroke Length	:	110 mm
Overall Dimension of the Engine	:	785*527*877 [Length *Width*Height]
Type of Fuel Injection	:	Direct Injection
Starting	:	Hand Start

Table 2: Current Required from Power Source for different electrolyte per litre (EPL)

For 500 ml of Water

KOH, NaOH, K_2CO_3 pellets (EPL)	HHO gas produced by a Dry Cell (in lpm)	Current Required from Power Source (A)
10 no.	0.5	4
20 no.	1	8

Table 3: HHO Gas Generation (in lpm) for different engine capacities

Engine Capacity (in cc)	HHO gas produced by a Dry Cell (in lpm)
500	0.30
800	0.35
1100	0.40
1800	0.60
2600	0.75

IV. RESULT AND DISCUSSION

The results of both the performance and exhaust emission test where first done without the introduction of HHO gas with the diesel fuel in a constant speed of 1500 rpm twin cylinder direct injection diesel engine with varying load range of 0-20kg, and the results were recorded. And then both the performance and exhaust emission test where done using introduction of constant HHO gas at a flow rate of 0.45 lpm produced by the process of electrolysis using three different electrolytes such as (KOH(aq), NaOH(aq), K_2CO_3(aq)) with the diesel fuel as an additive in a twin cylinder direct injection diesel engine with constant engine speed and load.

Performance Characteristics:

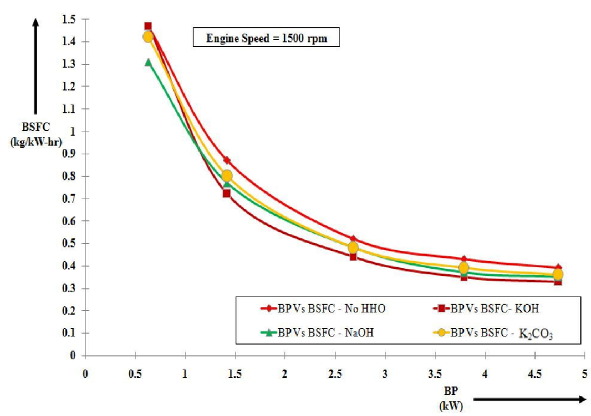

Figure 2: Effect of BSFC with BP

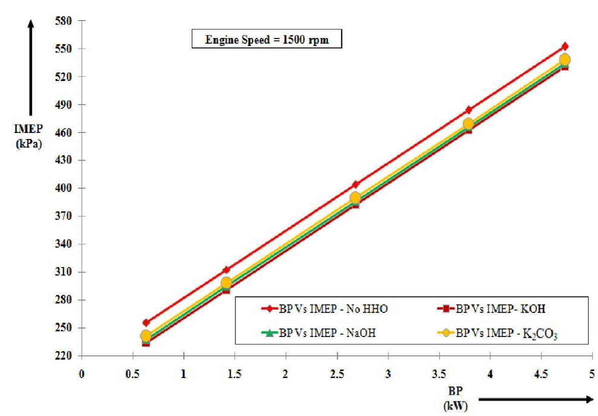

Figure 3: Effect of IMEP with BP

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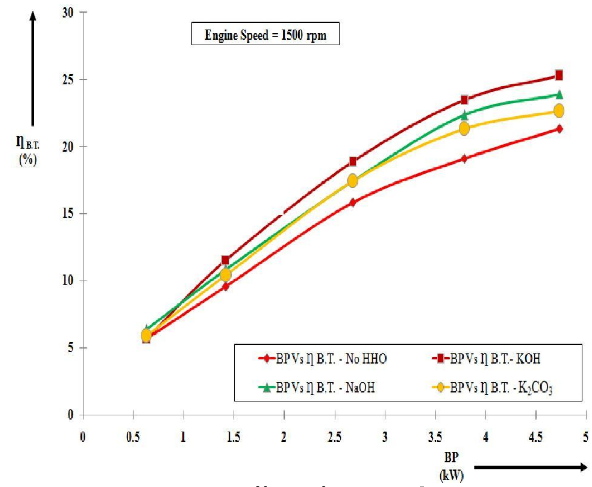

Figure 4: Effect of $\eta_{B.T.}$ with BP

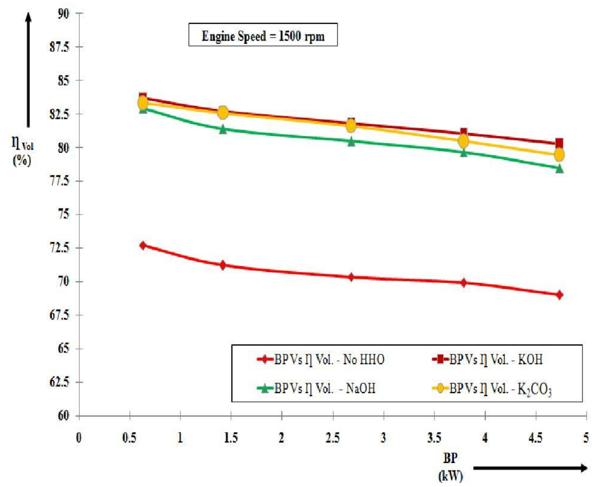

Figure 5: Effect of $\eta_{Vol.}$ with BP

Here in the above performance graphs in fig. 2 it shows the effect of brake specific fuel consumption (BSFC) with brake power (BP), the BSFC's for all the three electrolytes are lesser than that of normal diesel. This indicates that by usage of HHO gas decreases the BSFC because some amount of diesel is replaced by HHO gas during the process of combustion; so some amount of required input energy is supplied by HHO gas and amount of diesel required to produce the equivalent energy is saved. In fig. 3 it shows the effect of indicated mean effective pressure (IMEP) with BP, the IMEP's for all the three electrolyte are lesser than the normal diesel without HHO gas introduction. This happens as a result of HHO gas and air mixture after combustion inside the diesel engine increases the concentration of water vapour due to complete combustion thereby reducing the temperature and pressure inside the combustion chamber. The graph plotted in fig 4. showing the effect of brake thermal efficiency ($\eta_{B.T.}$) with BP, the $\eta_{B.T.}$'s of all the three electrolytes are greater than that of normal diesel without HHO gas introduction. The increase in the $\eta_{B.T.}$ is because of increase in the BP of the engine. Increase in the BP is because more energy is released by the addition of HHO gas and diesel fuel during the process of combustion compared to energy released by only diesel fuel. In the graph shown in fig 5 the effect of volumetric efficiency ($\eta_{Vol.}$) with BP, the $\eta_{Vol.}$'s of all the three electrolytes are greater than that of normal diesel without HHO gas introduction. The increase in the $\eta_{Vol.}$ is because more volume of the mixture is entering inside the combustion chamber with respect to engine swept volume when the added fuel is sent inside the combustion chamber.

Exhaust Emissions Characteristics:

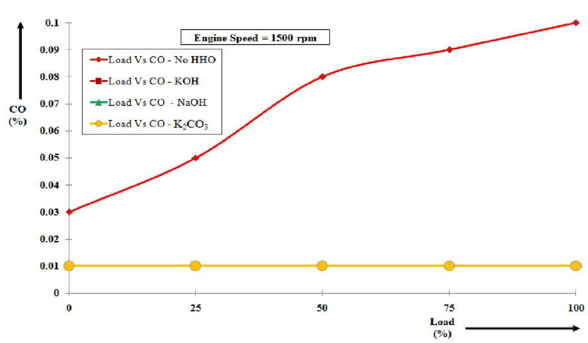

Figure 6: Effect of CO with Load Applied

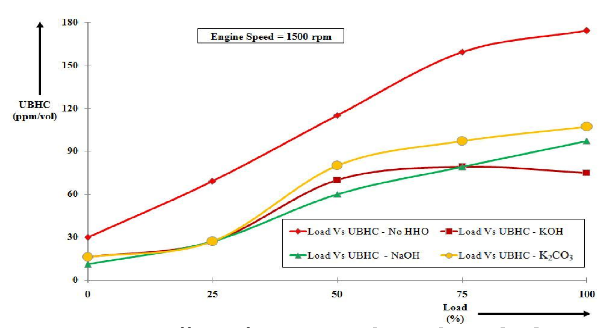

Figure 7: Effect of UBHC with Load Applied

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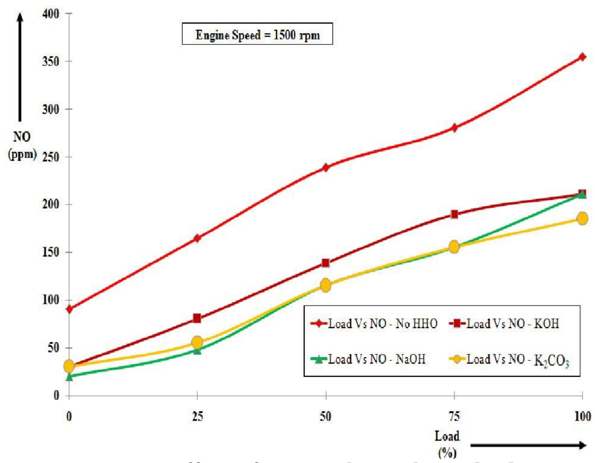

Figure 8: Effect of NO with Load Applied

As the above fig 6 shows a graph related to the effect of carbon monoxide (CO) emission with load applied and fig 7 showing a graph related to the effect of unburned hydrocarbon (UBHC) emission with load applied the concentrations of both CO and UBHC has drastically decreased because the formation of water vapour does not allow deposition of the carbon on the cylinder wall and keeps the combustion chamber clean which further increases combustion efficiency. In fig 8 presenting a graph related to the effect of nitrogen monoxide (NO) emission with load applied shows a radical decrease as the load increases. This decrease is due to the presence of water vapour in the combustion chamber which 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.

V. Conclusion

In this research work the effectiveness of HHO gas as an additive to enhance the performance and emission characteristics of twin cylinder diesel engine was studied and found out that by among these three different electrolytes (KOH(aq), NaOH(aq), K_2CO_3(aq)) which were added into the water to diminish hydrogen and oxygen bonds, to form HHO gas, KOH(aq) was specified as the most appropriate electrolyte. When referring all the graphs plotted above comparing all the three electrolytes The introduction of MMO coated titanium plated dry cell has shown a better reliability and durability than the titanium plates and that of the 316L stainless steel plates in terms of extended life, both performance and exhaust emission characteristics.

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