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REDUCTION OF EMISSION POLLUTANTS IN GASOLINE ENGINE BY USING HHO (OXY-HYDROGEN) GAS INTO INTAKE MANIFOLD

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Abstract: Oxy-Hydrogen gas is an alternative fuel to be used alongside gasoline or with other fuels for its feature of having high octane number and also increases the energy produced per mole of fuel during ignition process. In the present study, Oxy-hydrogen (HHO) gas is produced by electrolysis process and is being supplied with gasoline fuel into intake manifold of 99.27cc single cylinder (Bajaj CT100) gasoline engine. In electrolysis process distilled water with two parallel plates, made up of brass alloy having 10mm distance between them and Potassium Hydroxide (KOH) as catalyst is used for the production of HHO gas. The numbers of performance parameters that evaluated in the present study are carbon monoxide emission (CO), carbon dioxide emission (CO_2), unburnt hydrocarbon emission (HC) and production rate of HHO gas. The main variables taken in this work are quantity of distilled water, Potassium Hydroxide (KOH) pellets and distance covered. Experimental results show that maximum production rate of HHO gas is 150.72ml/min, when the quantity of potassium hydroxide pellets 12g/l is used respectively. Reduction in various pollutants like carbon monoxide emission (CO) is 42%, hydrocarbon emission (HC) is 16% and carbon dioxide emission (CO_2) is 28%. Utilization of HHO gas with gasoline is also helpful in the reduction of fuel consumption up to 26% respectively.

Keywords: Gasoline engine, Hydrogen cell, Oxy- hydrogen gas, safety container and Exhausts emission

I. INTRODUCTION

Development of any country is based on availability of energy and its usage. At a time the main sources of energy are non renewable resources and these are getting scarce to meet the future energy demand. Also the development in automobile industry and emissions produce by these has generated a need to search for alternative fuels. Some alternative fuels are biodiesel, bio-ethanol, biogas, solar energy and oxy-hydrogen gas. In present study, oxy-hydrogen gas as an alternative is used into intake manifold of gasoline engine for the reduction of emission pollutants and also, to enhance the engine performance without changing design parameters of engine. Due to several merits of that system, lot of researches have been conducted in the past years. (Khidr et al.) **[1]** reviewed the effect of hydroxy (HHO) gas addition on gasoline engine performance and emissions and concluded that thermal efficiency of Skoda Felicia 1.3 GLXi engine has been increase up to 10%, when HHO gas introduced into the air/fuel mixture, consequently reducing the fuel consumption up to 34% and the concentration of NO_x, CO and HC gases has been reduce to almost 15%, 18% and 14% respectively on average, when HHO is introduce into the system. (Ammar A. Al-Rousan) **[2]** Proposed reduction of fuel consumption in gasoline engines by introducing HHO gas into intake manifold and they concluded that the use of HHO in gasoline engines enhances combustion efficiency, consequently reducing the fuel consumption and thereby decreasing the pollution. Surface area of electrode needed to generate sufficient amount of HHO is 20 times that of the piston surface area. (Sa'ed A. Musmar et al.) **[3]** Analysed the effect of HHO gas on combustion emissions in gasoline engines and concluded that the combustion efficiency of an engine enhanced when HHO gas was introduced to the air/fuel mixture of this procedure also reduced the emission pollutants and HC concentration facilitates was highly affected by the engine speed and presence of HHO gas. (H.H. Masjuki et al.) **[4]** have studied the production optimization and effect of hydroxyl gas on a CI engine performance and emission fueled with biodiesel blends and proposed that blend of biodiesel in CI engine reduce CO and HC emissions by 20% and 10% respectively in the presence of HHO. (Ali Can Yilmaz et al.) **[5]** reviewed the effect of hydroxyl (HHO) gas addition on performance and exhaust emission in compression ignition engine and found that Uniform and improved mixing of hydroxyl-air and oxygen content of HHO stimulate combustion, which has a major effect on SFC. Using an adequate capacity system and HHO gas appropriated fuel addition to obtain adequate combustion which yield reputable reduction of HC and CO emissions. (Mustafa Ozcanli et al.) **[6]** analysed the utilization of HHO (Hydroxy) and hydrogen enriched castor oil biodiesel in compression ignition engine and concluded that pure hydrogen or hydroxy enriched intake air gas increased power and torque outputs slightly and specific fuel consumptions was reduced. CO emission reductions were observed with H_2 + CME20 and HHO + CME20 usage up to 27% and 21% respectively. (Husenyin Turan Arat et al.) **[7]** Proposed the effect of using hydroxyl – CNG fuel mixtures in a non-modified diesel engine by substituting diesel fuel. The addition of HHO-CNG mixture has a positive effect of combustion process enhancement. Brake torque, brake power and brake thermal efficiency outputs are improved in connection with the combustion characteristics of hydrogen and natural gas, all engine exhaust emissions are improved (including NOx) with reduced BSFC. 25HHO-CNG + pilot diesel fuel mixture is more superior to HHO + pilot diesel from fuel economy, power and torque point of view due to better combustion. (P. V. Manu et al.) **[8]** Experimentally investigated an on-board dry cell electrolyzer in a CI engine working on duel fuel mode. When HHO gas was introduced to the engine, BTE was found to be increased with increasing flow rates of HHO gas. The maximum BTE obtained was 34.99 % at a load of 14.7 kg (3.7 kW) with HHO gas flow rate of 2 LPM. With the addition of HHO gas, some amount of diesel fuel gets replaced by HHO gas resulting in decreased diesel consumption. The reduction in fuel consumption was due to better combustion. Since the diesel fuel consumption decreases with addition of HHO gas, the BSFC also decreases accordingly. The addition of HHO gas in intake manifold is expected to reduce the air intake and the oxygen present in the HHO gas will be sufficient for the combustion of hydrogen. So there will be excess amount of air due to reduction in fuel consumption, which results in increased in air-fuel ratio. ITE is due to better mixing of hydrogen with air which results in better combustion. In hydrogen enriched engines, it was found that the ITE increases with increase in HHO gas addition. (TS De Silva et al.) **[9]** proposed to increase fuel efficiency in spark ignition engines determined a convenient design for an efficient HHO generator. 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. (R. B. Durairaj et al.**)** **[10]** analysed HHO gas with bio diesel as a duel fuel with air preheating technology and concluded that the utilization of oxy-hydrogen with bio-diesel in internal combustion engines, the HHO compounds leads to increase in efficiency, torque and horse power of the engine, it also increases the performance of the engine. Heat energy is recovered from the exhaust gases, which causes lower heat addition, thus improving engine thermal efficiency. NO_x emission reduced with the exhaust heat recovery system and uniform or better combustion occurred due to pre heating of inlet air, which also caused lower engine noise. (Harshal Vashi et al.) **[11]** studied reduction of fuel consumption in engines using HHO gas and proposed an HHO generating device which was compact and could be installed in the engine compartment itself. From this design the fuel utility reduced from 15% to 30%. It also improved the efficiency of the engine by increasing the engine torque. This system also helped in reducing the pollution and maintaining the green house effect. Results concluded that the generation of HHO depends upon two parameters namely Time and duty cycle of the PWM signal. Greater the time and duty cycle more the HHO generated was more, if the non zero frequency was kept constant. (Yadav Milind S et al.) **[12]** investigated on generation methods for oxy-hydrogen gas, its blending with conventional fuels and effect on the performance of internal combustion engine. In this study Oxy-hydrogen gas was produced by electrolysis of water using caustic soda or KOH as the catalyst. Water as one of the by-products 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 when required. 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. (Abdel-Aal HK) **[13]** concluded that Fundamental to the creation of a hydrogen economy, viable, *safe* and affordable hydrogen-energy-system. Examining carefully some of the key properties of hydrogen that are related to fire and explosion, it is found that hydrogen is combustible over a wide range of concentrations. At atmospheric pressure, it is combustible at concentrations from 4% to 74.2% by volume. It has the highest flame velocity among gases and its ignition energy is very low, which is 32% less than methane gas. The problem of ―safe hydrogen‖ is tackled using a new theoretical approach. **(**Brown Y) Brown‘s gas **[14]** (HHO gas) was introduced as an alternative clean source of energy. A system to generate HHO gas was built and integrated with Honda G 200 (197 cc single cylinder engine). The results showed that a mixture of HHO, air, and gasoline caused a reduction in the concentration of emission pollutant constituents and an enhancement in engine efficiency. The emission tests were done with varying engine speed. The results showed that nitrogen monoxide (NO) and nitrogen oxides (NO_x) reduced to about 50% when a mixture of HHO, air, and fuel was used. Moreover, the carbon monoxide concentration reduced to about 20%. Also a reduction in fuel consumption was noticed and which ranged between 20% and 30%.

Abbreviations

SI	SPARK IGNITION
HHO	OXY- HYDROGEN
KOH	POTASSIUM HYDROXIDE
LPM	LITRE PER MINUTE
H_2	HYDROGEN

O_2	OXYGEN
CO	CARBON MONOXIDE
CO_2	CARBON DIOXIDE
HC	HYDROCARBON
CR	COMPRESSION RATIO
TFC	TOTAL FUEL CONSUMPTION
V	VOLT
η	EFFICIENCY
PPM	PARTS PER MILLION

II. EXPERIMENTAL SETUP

The setup is installed at University institute of engineering and technology, Kurukshetra (India). The setup was made to investigate the effect of utilization of Oxy-hydrogen (HHO) gas into intake manifold of gasoline engine. The experimental setup is shown in fig.1.

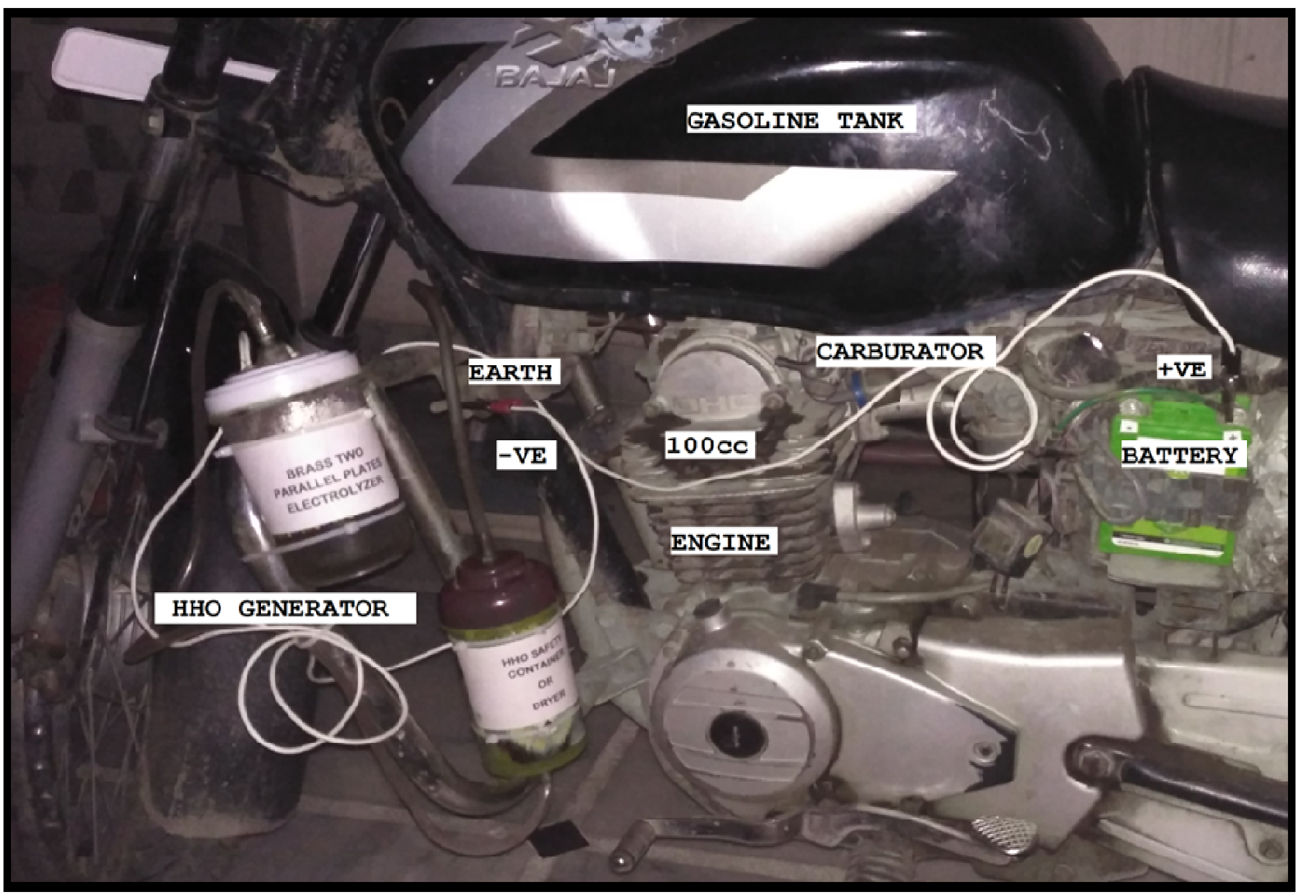

Fig.1 Experimental setup of Oxy-hydrogen system with gasoline engine

A. Components of experimental setup

The main components of entire experimental setup are given below:

- 100cc gasoline engine
- 12 volt battery
- HHO generator
- Catalyst
- Safety container
- Air filter

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1) Description of HHO Generator:

The basic principle of oxy-hydrogen gas generator (shown in Fig.2) is based on electrolysis process and the main terms involved with oxy-hydrogen generator are: Electrolysis process, Catalyst, Electrodes and Safety container is shown in fig. 3

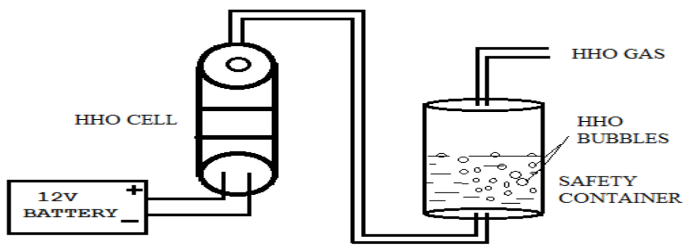

Fig.2 Principle of oxy-hydrogen generating system.

2) Electrolysis process: It is defined as the process where the separation of positive and negative ions take place that present in the electrolyte by passing the direct electric current in the solution. An electrical current is applied between the pair of electrodes that immersed in the solution. Each electrode attracts the ions due to opposite charge. Therefore, cations (positive charge) move towards cathode while anions (negative charge) move towards the anode and that process results in the production of oxy-hydrogen gas from the water and catalyst solution.

3) Catalyst: Catalyst is a substance which accelerates the speed of reaction and in electrolysis process catalyst increase the production rate of oxy-hydrogen gas from the water. In present study potassium hydroxide is utilized as a catalyst, which has a good capability to separate the hydrogen bonds from the water and this catalyst is effective in the generation of oxy-hydrogen from the water from other catalyst.

4) Electrodes: In present study, to get the higher efficiency and to reduce the power consumption, two parallel plates of brass electrodes immersed in the electrolyte solution for electrolysis process are used, where electrolyte solution is the mixture of water and catalyst viz. potassium hydroxide (KOH) pellets.

5) Safety Container: Safety container is an important component in the process. The handling of continuously generating hydrogen gas is very difficult and lead to explosion. To overcome this problem safety container is provided. The oxy-hydrogen produced in the HHO cell is transferred to the safety container after that, it is mixed with fresh air coming from the air filter. In case of explosion, safety container prohibits the blast of production chamber.

Fig.3 Parts of generating system

III. WORKING OF THE SYSTEM

The working of the system is very simple. In this system Oxy-hydrogen generator is used to generate the Oxy-hydrogen gas and the schematic diagram of HHO system with gasoline engine is shown in the fig. 4.

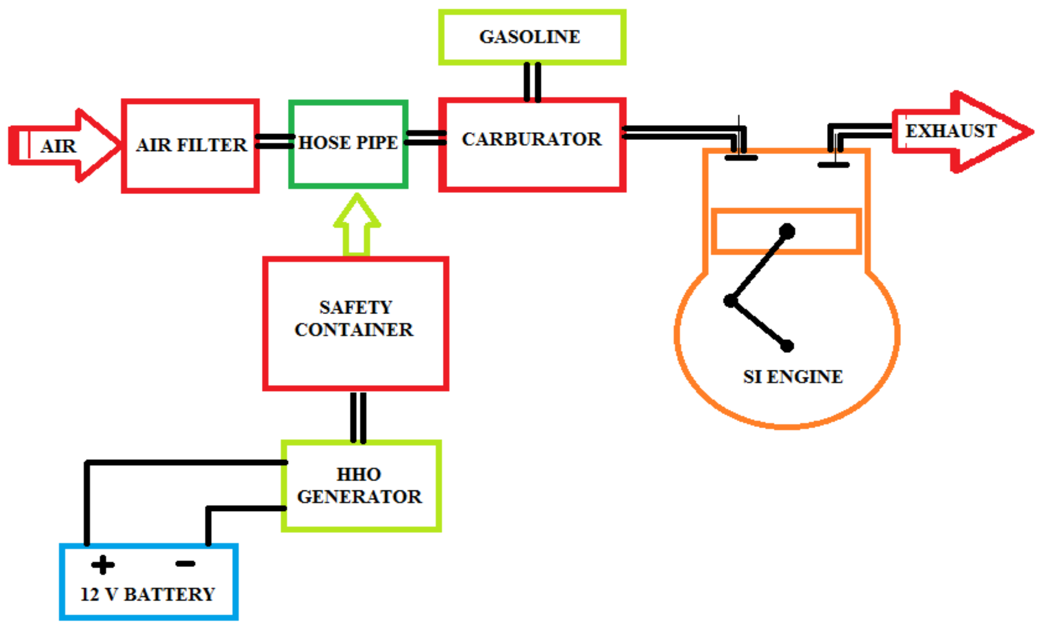

Fig.4 Schematic diagram of Oxy-hydrogen system with gasoline engine

This oxy-hydrogen gas gets mixed with fresh air coming from the atmosphere after passing through the air is filter and that mixed air supplied to the carburettor, where it mixes with gasoline fuel to according the load on the engine. Finally air/fuel mixture is supplied to intake manifold of gasoline engine where, its combustion takes place and chemical energy of mixture gets converted into heat energy. This heat energy is utilized to do the mechanical work and cycle repeated again.

IV. RESULTS AND DISCUSSION

The performance of gasoline engine using Hydroxyl gas (HHO) as an additional fuel in intake manifold is evaluated in the term of distance covered, reduction in pollutants likes carbon dioxide, carbon monoxide, unburnt hydrocarbon emission and production rate of oxy hydrogen (HHO).

A. Production Rate of Oxy-hydrogen (HHO) gas

In experimental setup, electrolysis process is used for the production of oxy hydrogen gas from the strong solution, which is the combination of water (H_2O) and potassium hydroxide (KOH) having initial temperature of 29^0C and final temperature of 40^0C to 45^0C. Potassium hydroxide is added only to increase the reaction rate, which further increases the production rate of oxy-hydrogen.

Production rate of HHO gas = Volume produced / Time taken
Volume produced = $\pi R^2 H$

B. Effect of Potassium Hydroxide on Production Rate of HHO

In oxy-Hydrogen system potassium hydroxide pellets are used with water, to make the strong solution, which is helpful to increasing the reaction rate. In strong solution increase in reaction rate means increase in production rate of oxy-hydrogen gas. Figures 5(a), 5(b) and 5(c) shows the effect of KOH pellets on production rate of oxy-hydrogen gas and also on time taken to produce its required quantity, When the quantity of KOH pellets continuously increase from 2 gram to 6 gram in the constant quantity of 500 ml water, the production rate of HHO gas continuously increases and time taken for that process continuously decreases from 10 minute to 2 minute respectively. Maximum production rate of HHO gas is 150.72 ml/min, when the quantity of KOH pellets is 6 gram and time taken is 2 minute respectively.

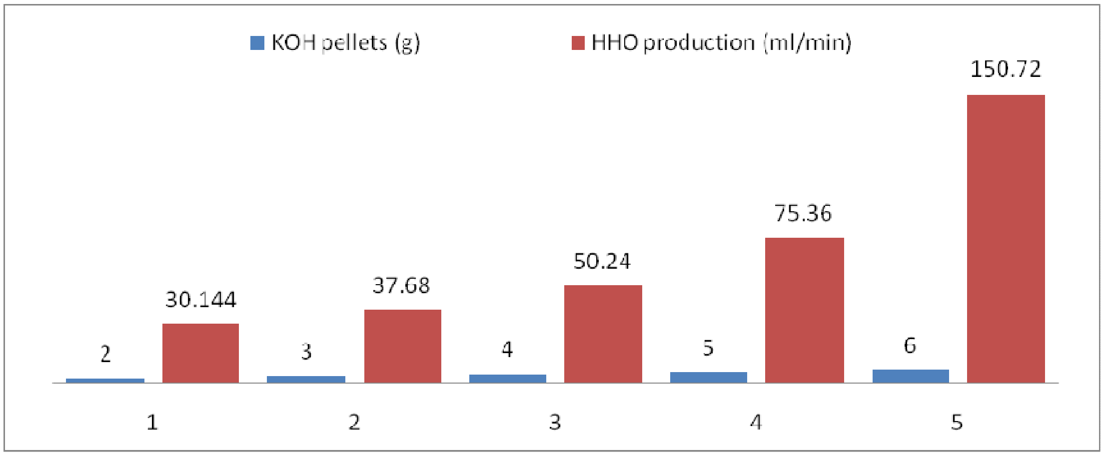

Fig.5 (a) Effect of KOH pellets on production rate of oxy-hydrogen gas

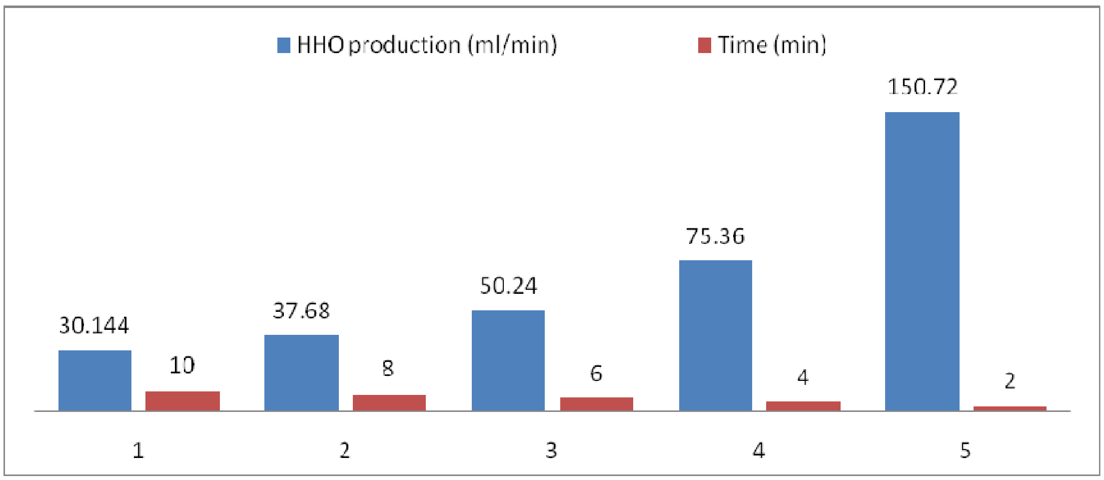

Fig.5 (b) Effect of KOH on time taken for the production of oxy-hydrogen gas

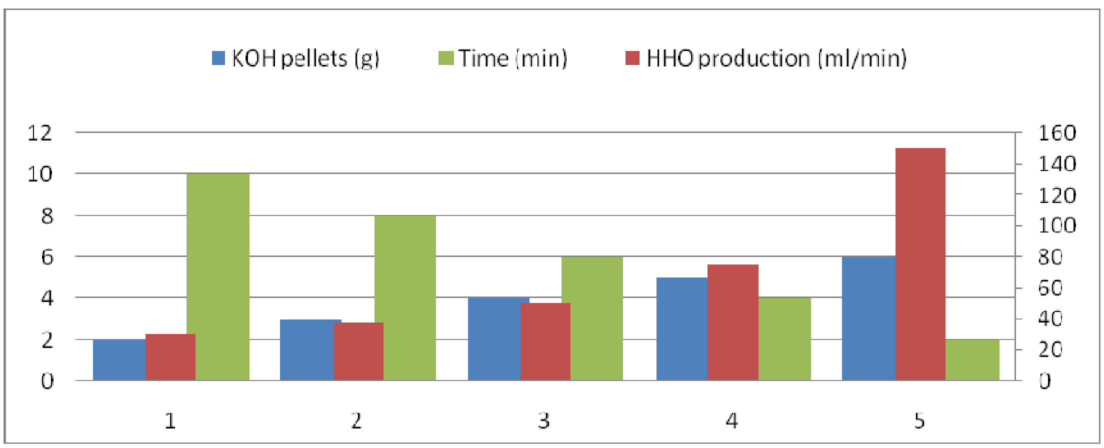

Fig.5 (c) Combined view of KOH, production rate of oxy-hydrogen gas and time taken

C. Effect of HHO gas

The performance of the gasoline engine is greatly affected by using HHO gas in intake manifold. The main parameters of gasoline engine that affected by HHO gas is fuel consumption, fuel efficiency, distance covered, contents of carbon dioxide, carbon monoxide and hydrocarbon pollutants in the atmosphere. With the help of experimental data, the effect HHO on these parameters is explained as:

1) Effect on Distance Covered

Figure.6 shows that when the fuel consumption continuously increases from 100 ml to 500 ml in the vehicle using gasoline engine, the changes take place in the distance covered with or without using HHO gas. To show the effect of HHO gas on distance covered, reading was taken for nine different fuel consumptions during testing. Minimum distance covered without HHO is 5.2 km and with HHO is 7.6 km, when gasoline fuel consumption is 100 ml. similarly; maximum distance covered without HHO is 29.5 km and with HHO is 39.2 km, when the fuel consumption is 500 ml, respectively. Graph shows that the utilization of HHO gas with gasoline is beneficial in distance increment than without HHO.

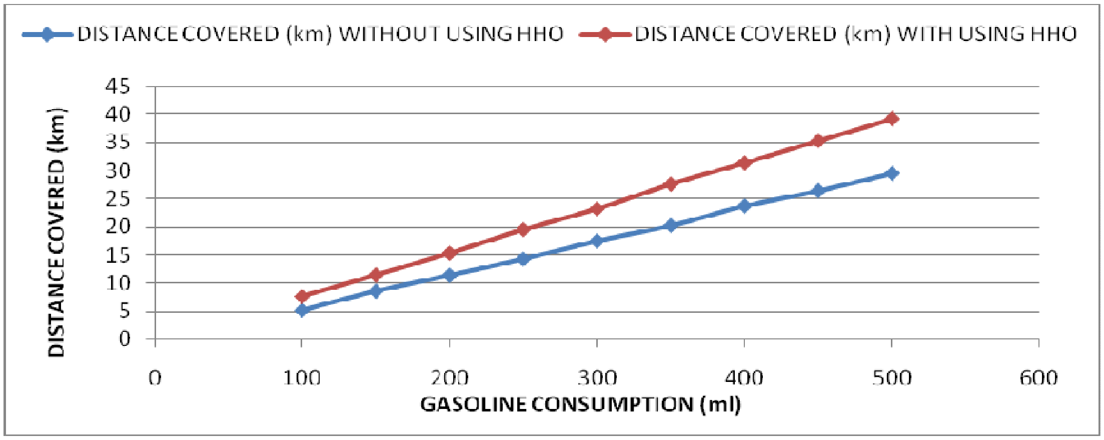

Fig.6 Effect of HHO on distance covered

2) Effect on Carbon Dioxide Emission

In figure.7, distances covered are plotted against the carbon dioxide produced from the gasoline engine. Figure.7 show that when the distance covered by the vehicle continuously increases from 0 to 70 km using gasoline, the changes take place in carbon content produced from the gasoline engine with or without using HHO. To show the effect of HHO gas on carbon content, Readings are taken for eight different distances covered during testing. It shows that when the distance covered is 20km, the production of carbon dioxide is level 1.82 % ppm at idling, without HHO and level 1.64 % ppm at idling. with HHO respectively. Similarly when the distance covered increased up to 70km the carbon dioxide without HHO is 1.93 idling % ppm. and with HHO is 1.19 idling % ppm. Finally the utilization of HHO in gasoline engine is beneficial for the reduction of carbon dioxide emission.

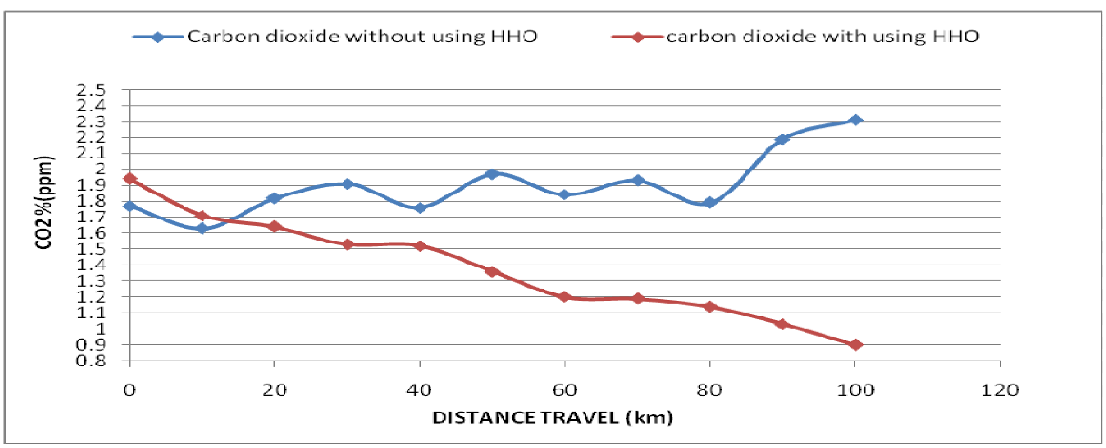

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Fig.7 Effect of HHO on carbon dioxide emission

3) Effect of HHO on Carbon Monoxide Emission

In figure.8, distances covered is plotted against the carbon monoxide emission and figure shows that, when the distance covered by the vehicle continuously increases from 0 to 100 km using gasoline, the changes takes place in carbon monoxide content produced from the gasoline engine with or without using HHO. To show the effect of HHO gas on carbon monoxide content, readings are taken for eleven different distances covered during testing. When the distance covered is 30 km, the production of carbon monoxide is 2.119 % ppm without HHO and 1.83 % ppm with HHO respectively. Similarly when the distance covered increased up to 100 km the carbon monoxide without HHO is 3.136 % ppm and with HHO is 0.05 % ppm respectively.

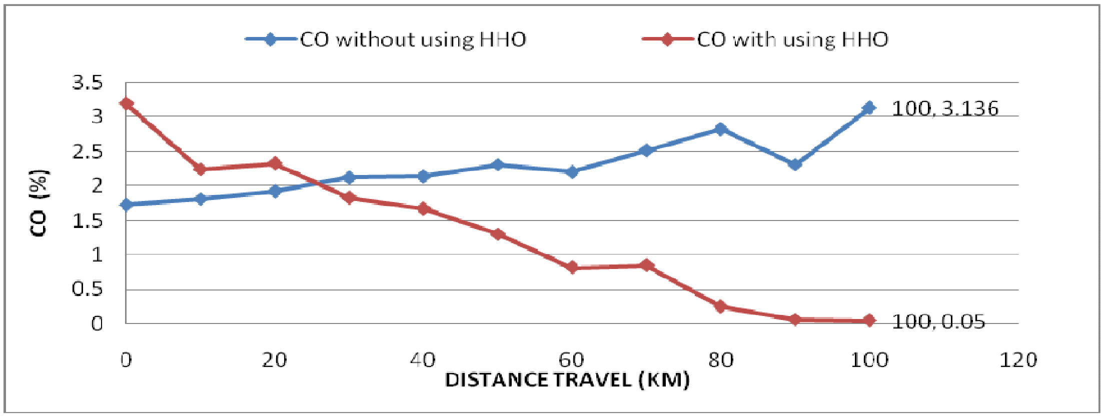


Fig.8 Effect of HHO on carbon monoxide emission

4) Effect on hydrocarbon (HC) content

In figure.9, distance covered with or without using HHO is plotted against the unburnt hydrocarbon produced from the gasoline engine. It shows that when the distance covered is continuously increased from 0 to 100 km, the fluctuation in the unburnt hydrocarbon is not continuous in either increasing or decreasing order. Minimum value of unburnt hydrocarbon without HHO gas is 429, when the distance covered is 40 km and with HHO gas is 314, when the distance covered is 70 km respectively. Finally reduction in unburnt hydrocarbon takes place with the utilization of HHO gas in intake manifold of the gasoline engine. Increment and decrement of the unburnt hydrocarbon in the gasoline engine is directly connected to the fuel consumption and engine efficiency increases, when the decrement takes place in the generation of unburnt hydrocarbon.

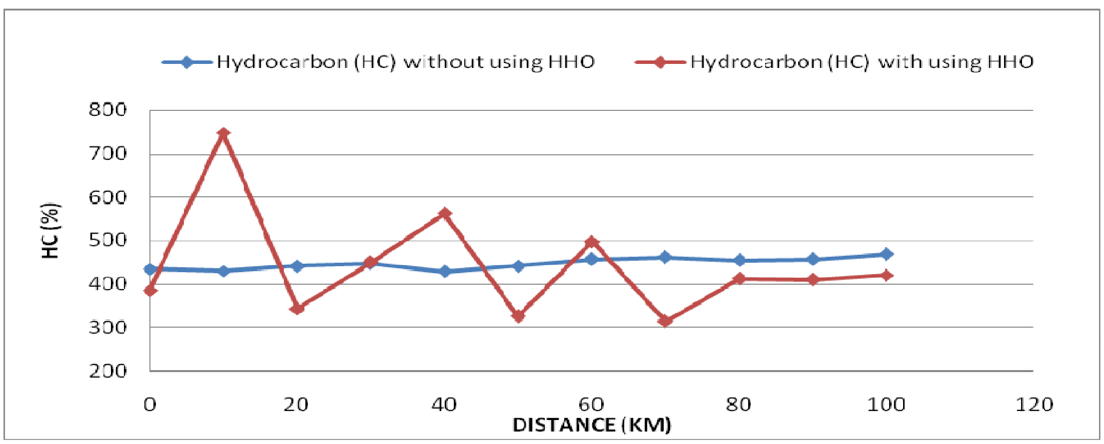
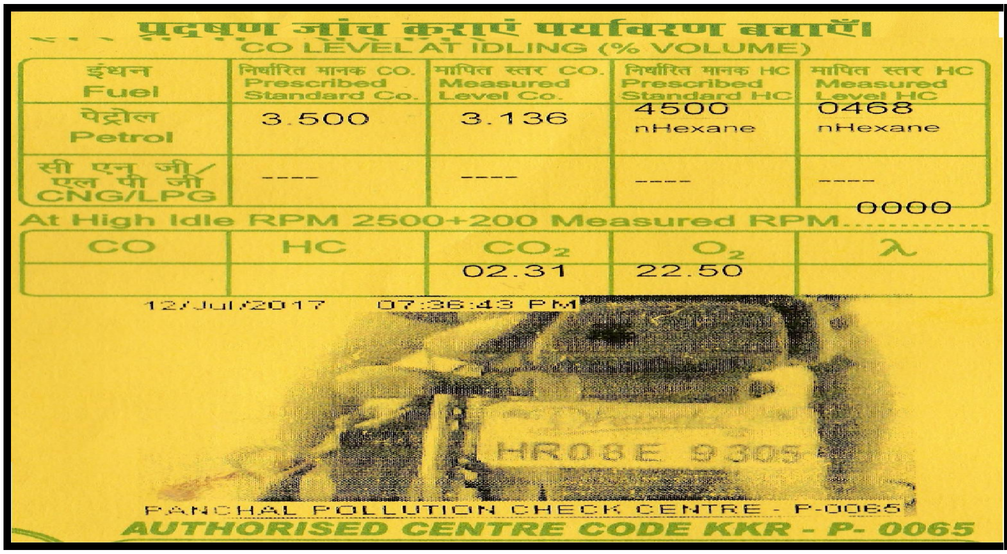


Fig.9 Effect of HHO on unburnt hydrocarbon content

5) TECNO Test Gas Analyzer

Techno test gas analyzer is a machine which is used to measure the percentage of CO_2, CO and HC exhaust emissions. Test report of exhaust emissions without or with using HHO is shown in the figure.10 and figure.11 respectively.



प्रदूषण जांच कराएं पर्यावरण बचाएँ।

CO LEVEL AT IDLING (% VOLUME)

ईंधन Fuel	निर्धारित मानक CO. Prescribed Standard Co.	मापित स्तर CO. Measured Level Co.	निर्धारित मानक HC Prescribed Standard HC	मापित स्तर HC Measured Level HC
पेट्रोल Petrol	3.500	3.136	4500 nHexane	0468 nHexane
सी एन जी/ एल पी जी CNG/LPG	----	----	----	----

At High Idle RPM 2500+200 Measured RPM.......0000

CO	HC	CO_2	O_2	λ
		02.31	22.50	

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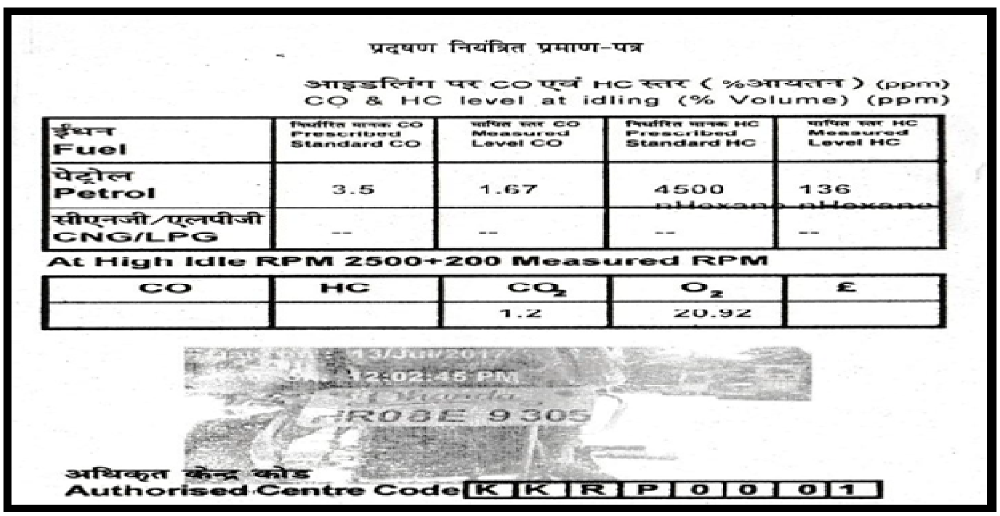
AUTHORISED CENTRE CODE KKR - P- 0065

Fig.10 Exhaust emission test report without using HHO



प्रदूषण नियंत्रित प्रमाण-पत्र

आइडलिंग पर CO एवं HC स्तर (%आयतन) (ppm)
CO & HC level at idling (% Volume) (ppm)

ईंधन Fuel	निर्धारित मानक CO Prescribed Standard CO	मापित स्तर CO Measured Level CO	निर्धारित मानक HC Prescribed Standard HC	मापित स्तर HC Measured Level HC
पेट्रोल Petrol	3.5	1.67	4500 nHexane	136 nHexane
सीएनजी/एलपीजी CNG/LPG	--	--	--	--

At High Idle RPM 2500+200 Measured RPM

CO	HC	CO_2	O_2	£
		1.2	20.92	

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Fig.11 Exhaust emission test report with using HHO

V. CONCLUSION

The main objective of utilization of oxy-hydrogen gas in gasoline engine was to reduce the hazardous pollutants from exhaust emission and the following conclusions emerged from the experiment:

- The best available catalyst was found to be potassium hydroxide (KOH).
- Reduction in fuel consumption of gasoline engine takes place up to 26% respectively.
- Utilization of oxy-hydrogen gas results in reduction of hazardous pollutants like carbon monoxide (CO) up to 42%, unburnt hydrocarbon (HC) up to 16% and carbon dioxide (CO_2) up to 28% respectively.
- Oxy-Hydrogen gas is an alternative and eco-friendly fuel that can be substituted as a secondary fuel without modification in engine.

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