Performance Analysis of Gasoline Engine by Addition of HHO Gas as a Secondary Fuel

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ABSTRACT

Brown's Gas (HHO) has been introduced to the auto industry as a new source of energy. This paper reviews the construct of a simple HHO generation system and its integration with the gasoline engine. The effect of hydroxyl gas (HHO) addition into gasoline fuel are evaluated on engine performance and emissions during previous research. The HHO cell was designed, constructed and optimised for maximum productivity of the cell in producing HHO gas per input power. Studies show that the parameters on which the productivity of the cell depends are number of neutral plates, distance between them and type and quantity of two catalysts of potassium Hydroxide (KOH) and Sodium Hydroxide (NaOH). The performance of a Skoda Felicia 1.3 GLXi gasoline engine was evaluated using HHO as a secondary fuel and the results showed 10% increment in gasoline engine thermal efficiency, 34% reduction in fuel consumption, 18% reduction in CO, 14% reduction in HC and 15% reduction in NOx. The results explained that addition of HHO gas into gasoline is an effective way of improving the engine performance and maintaining the exhaust emissions to an environment friendly limit compared to neat gasoline operations.

Keywords: *HHO Gas, Gasoline Engines , Hydrogen cell, Exhaust Emissions.*

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1. INTRODUCTION

In last two decades, internal combustion engines industry is intentioned greatly to use alternative fuel systems for much effectively combustion and less environmental pollution. The increasing demand for petroleum fuel associated with limited non-renewable stored quantities has resulted in a huge increase in crude oil prices. A trending global concern , towards lowering fuel consumption and emissions of internal combustion engines, is motivating researchers to seek alternative solutions that would not require dramatic modification in engine design. As such a solution is using H_2 as an alternative fuel to improve engine efficiency and reduce harmful emissions. It has been studied previously that using pressurized hydrogen gas as a fuel in internal combustion engines (IC engines) has many advantages such as more engine power and lower pollutant concentrations in exhaust gases. Additional note from [1] says that Hydrogen and compounds are the major players in energy world. The heating value of hydrogen is much higher than that of conventional fuels if taken as per unit of weight and hydrogen combustion is completely clean, producing only water vapor in the exhaust gas.

Also research is in progress for using hydrogen for transport as a main fuel (or supplement fuel) for internal combustion engines and for fuel cell. Hydrogen internal combustion engines have the potential for high power because of more energy per unit mass and high flame speed, high efficiency because of high flame speed that causes high rate of pressure rise in the cylinder and hence near constant-volume combustion and they also have near-zero emissions, except NOx at higher loads, because of the absence of carbon in the fuel molecular structure.[1]

Another option is blending H_2 with Natural Gas (NG).Natural gas is regarded as one of the most promising alternative fuels and is one of the cleanest fuels in combustion. Natural gas is a mixture of different gases where methane is its major component. The combustion of natural gas produces less emission than that of gasoline and diesel fuels due to its simple chemical structure and absence of fuel evaporation. But natural gas has the drawback of slow burning velocity and poor lean burn ability and this may lead to the incomplete combustion. One effective way to solve the problem is to mix the natural gas with a fuel that possesses the high burning velocity. Hydrogen is an excellent additive into natural gas in improving the burning velocity of mixture due to the high burning velocity of hydrogen. Adding a small amount of hydrogen into natural gas can improve the combustion characteristics and reduce exhaust emissions.[1]

2. LITERATURE REVIEW

Al-Rousan[2] have designed, integrated and tested a compact HHO generating device on a gasoline engine. Their results showed that nitrogen oxides (NOx), carbon monoxide (CO), and fuel consumption were reduced by 50%, 20%, and 30%, respectively, with an addition of HHO gas.

EL Kassaby [3] in his work showed the advantages of CO_2, CO and HC reduction, while NOx increased, with higher H_2 %, which are as follows: reduction of these 3 was attributed to enhanced combustion kinetics, as H_2 combustion produces the oxidizing species of OH and O radicals that benefit the chemistry of Hydrocarbons (HCs) combustion. Besides, gasoline fuel flow was reduced with H_2 enrichment to maintain constant global mixture equivalence and compare the engine performance with pure gasoline so, lesser HCs content is in the fuel, which cuts the formation of CO, CO_2 and HC and promotes economic fuel consumption. Furthermore, hydrogen has a higher diffusion coefficient than that of the gasoline, and so, the gaseous H_2 can disperse thoroughly in the charge and allow for greater mixture homogeneity and combustion completeness. On the other hand, NOx increase was attributed to the higher adiabatic flame temperature of hydrogen.[3]

Adding HHO to the fuel-air mixture has the immediate effect of increasing the octane rating of any fuel as explained by Al-Rousan[2]. Octane rating indicates how much a fuel can be compressed before it ignites. This fact causes the fuel-air mixture (without HHO) to ignite percent the density of air. Moreover, it is not a corrosive gas and can be used in engines with no toxic effects to humans. It ranks second in flammability among other gases, but if and when it leaks, hydrogen rises and diffuses to a non-flammable mixture quickly. Hydrogen ignites very easily and burns at a high temperature, but tends to burn out quickly. A mixture of hydrogen and air will burn when it contains as little as four percent up to as much as seventy five percent of hydrogen in the mix.

3. HHO GENERATOR (DRY CELL)

3.1 Experimental Setup and Test Procedure

HHO generator used in this study is shown in Fig 1. It consists of separation tank (1) which supplies the HHO cell (2) with continuous flow of water to prevent the increase in the temperature inside the cell and to provide continuous hydrogen generation. Oxygen–hydrogen mixture generated from the dry cell will be back to the top of the tank with some water droplets.

$$2H_2O \rightarrow 2H_2+O_2$$

Water droplets will separate and fall to the bottom of the tank with the rest of the water, while hydrogen and oxygen gases are directed to the engine intake manifold. The HHO flow rate was measured by calculating the water displacement per time according to the setup shown in Fig. 1. The HHO gas leaves the separation tank and flows into the water open pool (4) bushing the water down of the inverted graduated cylinder (3). The volume of gas collected in the graduated cylinder per unit of time was measured as the HHO flow rate. Therefore, the cell productivity can be calculated from the following equation:

HHO productivity ———

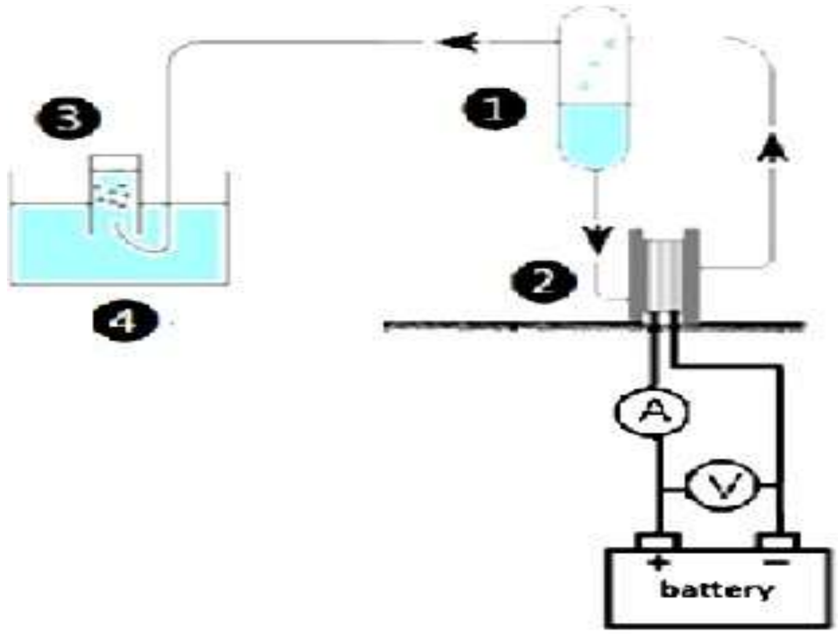

Fig-1: Schematic diagram of HHO gas generation system.

3.2 HHO Dry Cell System Description

Stainless steel tumblers were used as the electrodes. There are 16 electrodes 16*20*0.2 cm thickness, configured as shown in Fig. 2 in alternate form (+,2N,-), where (+) represents the positive electrode, (N) is neutral, and (-) is the negative electrode. Amperage flows from the negative battery terminal through the neutral plates to the positive plate and onto the positive terminal. Neutrals reduce the plate voltage, share the same amperage and increase surface area for HHO production. The gap between adjacent tumblers was limited to 1 mm using rubber gaskets. In addition, 20*24*1 cm thickness cover plates were made of acrylic to provide visual indication of electrolyte level. HHO cell is supplied by electrical energy from the engine battery which is recharged by the engine alternator. The cell productivity was tested without being connected to the engine with 2 different catalysts, KOH and NaOH, to find the best electrolyte with best concentration experimentally.

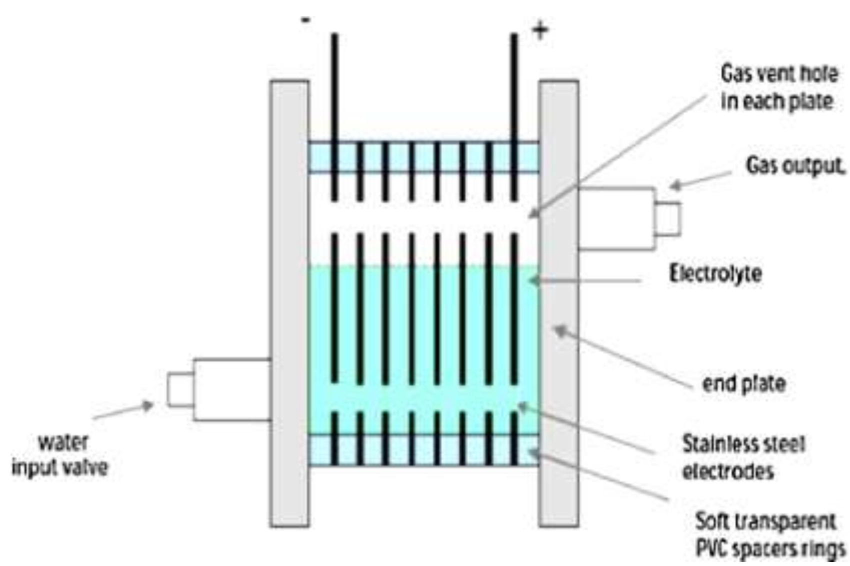

Fig-2: A schematic diagram of HHO dry cell

3.3 Engine and Test Bed Description

These research experiments were performed on Skoda Felicia engine whose specifications are shown in Table 1; tests were carried out at engine speeds of 1500, 2000 and 2500 rpm with different loads. Different engine parameters are measured, on a test rig which is illustrated in Fig. 3. Engine load was measured by Froude hydraulic dynamometer (2), engine speed and air flow rate by Vag-Com Diagnostic Systems (VCDS) (3), engine fuel consumption is measured by self-build inclined manometer (4), and engine emission by exhaust gas analyzer model TE488 (5). The testing is conducted for the taken engine operated with gasoline as base fuel without using the HHO cell and with using HHO cell connected to the inlet manifold. A constant speed test at variable load has been performed on this engine. The engine is tested and the measured data are collected at the same operating conditions for both cases of HHO/gasoline and gasoline fuel only.

Engine model	**Skoda Felicia 1.3 GLXi (1289cm^3)**
Engine type	In -line , 4 cylinders
Fuel system	Multi point fuel injection
Compression ratio	9.7:1
Max. power	67.66 HP @5500rpm
Max torque	102Nm @3750 rpm

Table-1: Engine Specifications

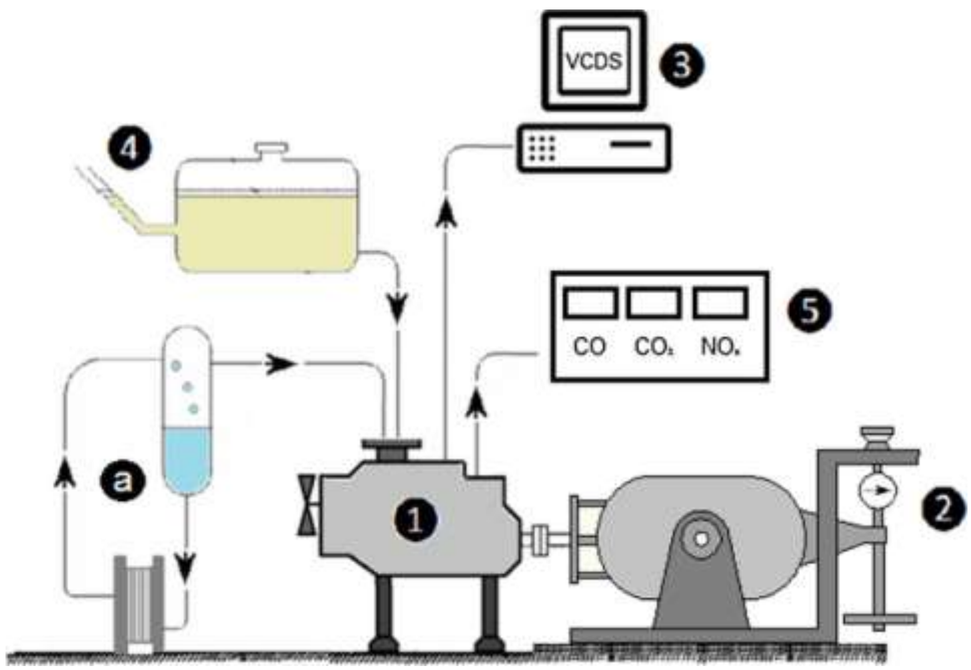

Fig-3: Schematic diagram of engine and test bed description.

3.4 HHO Cell Results

Fig. 4 shows the effect of KOH concentrations on the HHO cell average efficiency. It is found that 6 g/L of KOH as catalyst gives better efficiency at different engine speeds. It is also found that 4 g/L of NaOH gives better highest thermal efficiency compared to other NaOH concentration at different engine speeds as shown in Fig. 5.[3]

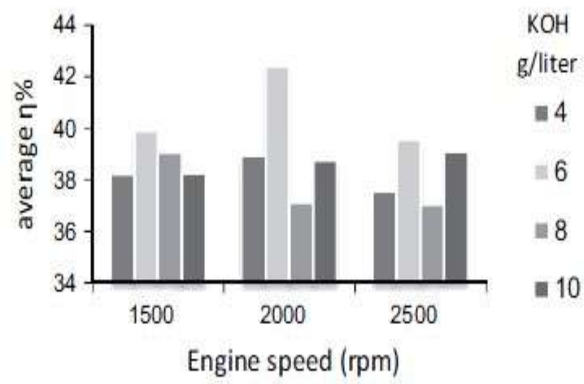

Fig-4: Average efficiencies for using different concentrations of KOH at different engine speeds.

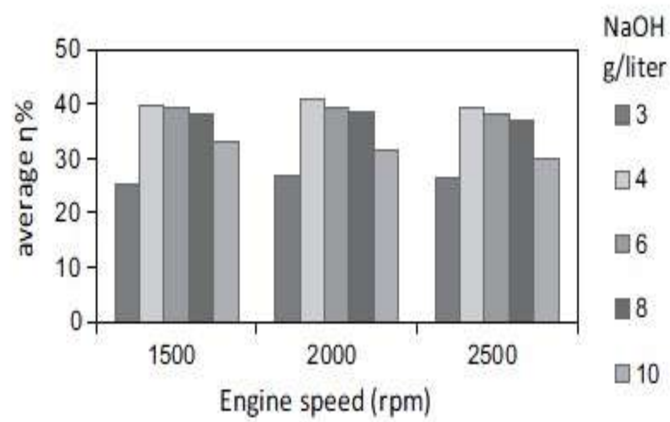

Fig-5: Average efficiencies for using different concentrations of NaOH at different engine speeds.

Fig. 6 compares the results of 6 g/L of KOH with those of 4 g/L of NaOH, and it is found that 6 g/L KOH gives highest efficiency at different motor speeds (see Fig. 6).

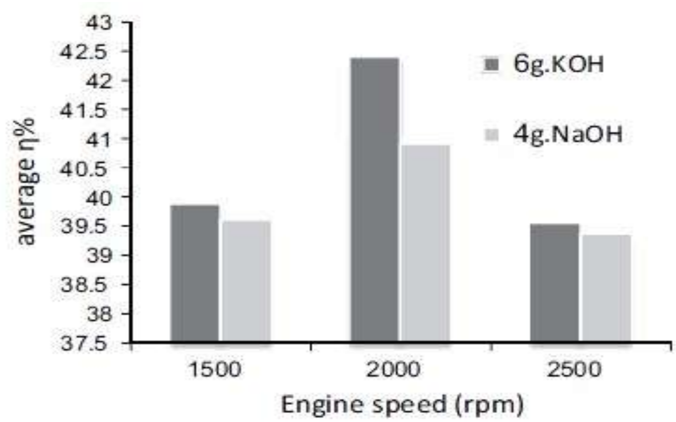

Fig-6: Average efficiencies for using concentrations of 6g KOH and 4g NaOH per litre at different engine speed.

3.5 Engine Performance

Figs. 7 and 8 show the effect of introducing HHO gas to the combustion on both thermal efficiency and specific fuel consumption. It is noted that HHO gas enhances the combustion process through increasing engine thermal efficiency and reducing the specific fuel consumption. Comparing HHO gas to commercial gasoline fuel, HHO is extremely efficient in terms of fuel chemical structure. Hydrogen and oxygen exist in HHO as two atoms per combustible unit with independent clusters, while a gasoline fuel consists of thousands of large molecules hydrocarbon. This diatomic configuration of HHO gas (H_2 and O_2) 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 wall at a much higher velocity than in ordinary gasoline/air combustion . The released heat of HHO facilitated breaking of the gasoline molecules bonds and hence increasing reaction rate and flame speed and then combustion efficiency is increased.

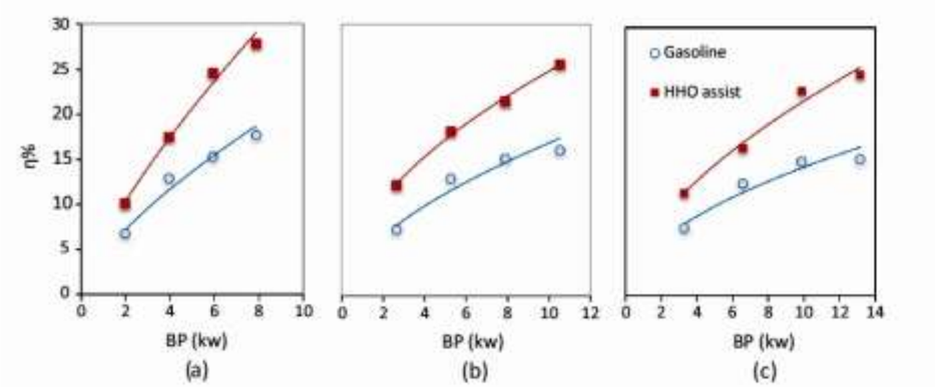

Fig-7: Overall thermal efficiency improvement with HHO over pure gasoline fuel at different engine speeds (a)1500rpm, (b)2000rpm and (c)2500rpm.

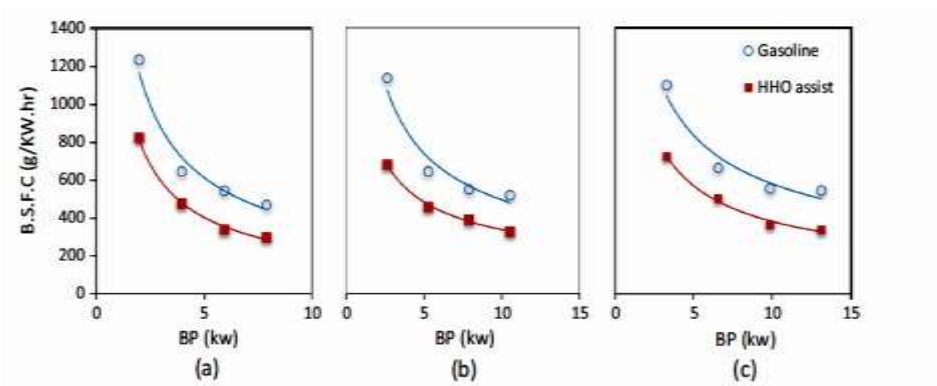

Fig-8: Effect of varying the engine dynamometer load on BSFC (a)1500rpm, (b)2000rpm and (c)2500rpm.

3.6 Engine Emissions

The effect of supplying the gasoline engine with HHO gas on the carbon monoxide CO, unburned hydrocarbon HC and nitrogen oxides NOx is presented in Figs. 9–11 respectively. CO is highly affected by the fuel to air ratio of the engine, so using a blend of HHO gas reduces significantly the presence of carbon monoxide in the exhaust due to decreasing the gasoline fuel consumption.

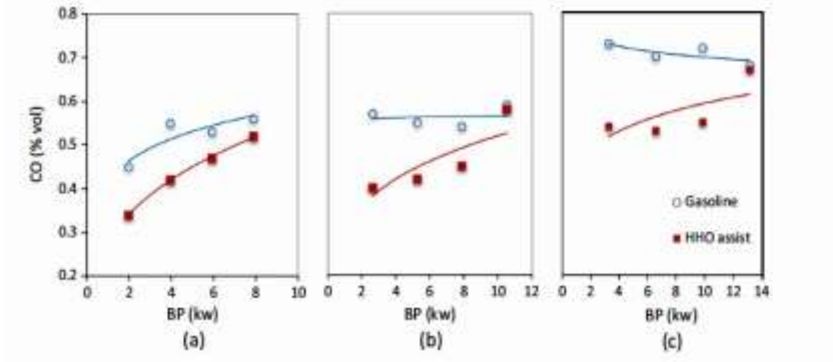

Fig-9: Effect of varying the engine dynamometer load on CO emission (a) 1500 rpm, (b) 2000 rpm, and (c) 2500 rpm.

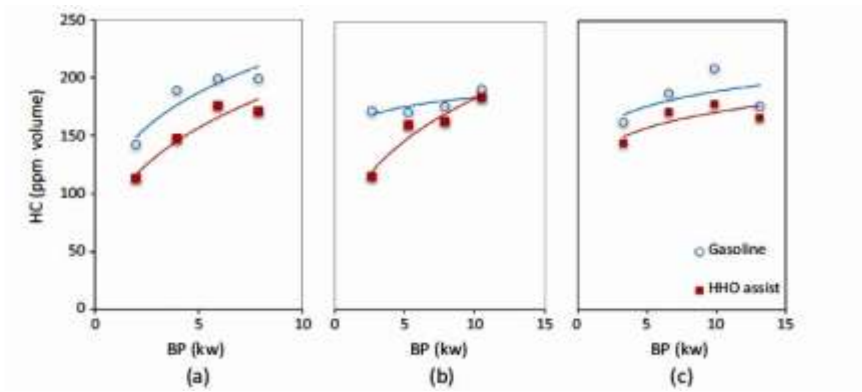

Fig. 10 Effect of varying the engine dynamometer load on HC emission (a) 1500 rpm, (b) 2000 rpm, and (c) 2500 rpm.

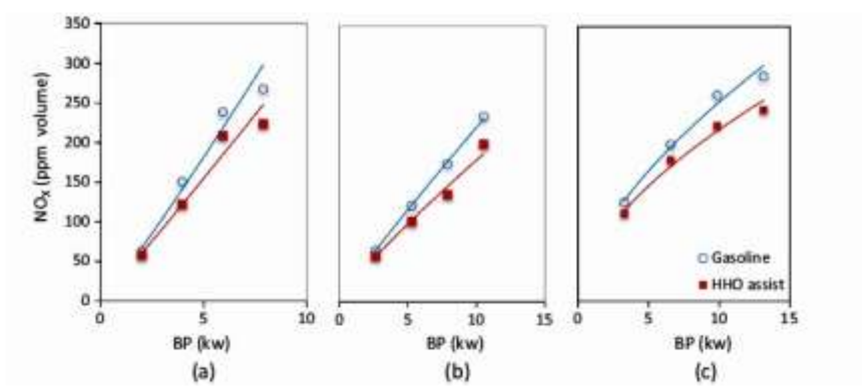

Fig-11: Effect of varying the engine dynamometer load on NOx emission (a) 1500 rpm, (b) 2000 rpm, and (c) 2500 rpm.

In Fig. 10, it is clear that, at fixed speed the unburned hydrocarbon increases as the load increases. This is due to more fuel is introduced to achieve the desire engine torque and hence it leads to increase in HC emission. It also noted that there is a reduction in HC emission when the engine runs with HHO/gasoline than gasoline fuel only. This is owing to the high O_2 % in HHO gas being injected into the intake manifold which in turn enhances the fuel oxidation process and reduces the HC emission. High NOx emission is usually increased with high flame temperature and excess air. Introducing HHO into the intake manifold results in reducing the amount of gasoline which leads to lean mixture and hence, resulting in reduction in the flame temperature. Therefore, lower NOx emission is obtained as shown in Fig. 11. HHO gas shifts all emission curves downward, since it enhances the combustion characteristics and consequently reduces the fuel consumption at any speed.

4. CONCLUSION

After studying from the papers , the laboratory experiments were carried out to investigate the effect of HHO gas on the emission and performance of a Skoda Felicia 1.3 GLXi engine. A new design of HHO fuel cell has been performed to generate HHO gas required for engine operation. The generated gas is mixed with a fresh air in the intake manifold. The exhaust gas concentrations have been sampled and measured using a gas analyzer. The following conclusions can be drawn.

1. HHO cell can be integrated easily with existing engine systems. No major hardware modifications are required.
2. The brake thermal efficiency has been increased up to 10% when HHO gas has been introduced into the air/fuel mixture which reducing fuel consumption up to 34%.
3. The concentration of NOx, CO and HC gases has been reduced to almost 15%, 18% and 14% respectively on an average.
4. The best available catalyst was found to be KOH, with concentration 6 g/L.
5. The proposed design for separation tank takes into consideration the safety precautions needed when dealing with hydrogen fuel.

As studied from the references, use of hydroxyl gas (HHO) can be recommended for improving gasoline engine performance and reducing exhaust emissions to an environment friendly limit. There is scope for further studies of HHO engines parameters like compression ratio and rank angle and its effects on engine performance and emissions

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