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Effect of HHO gas on fuel consumption and brake thermal efficiency of four stroke spark ignition engine with variable compression ratio

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Abstract*: In this study, HHO gas was produced by the process of water electrolysis. Electrolytes such that KOH is used as an electrolyte which reacts with electrode and produce the hydrogen. HHO gas was used as a supplementary fuel in a single cylinder, four strokes, spark ignition (SI) engine without any modification. In this experiment the HHO gas was supplied with intake air. The control valve was used for control the supply of HHO gas. The range of amount of HHO gas was placed between 2.57% to 2.74% with intake air. Also compression ratio was arranged at 7, 8 and 9 turn by turn. At this condition load was set at different condition at 1kg, 3kg, 5kg, 7kg and 9kg. After completing this experiment, an analysis was done. The fuel consumption was decreased when compression ratio and % of HHO gas was increased. Also the brake thermal efficiency was increased when compression ratio and % of HHO gas was increased.*

Key words: *Brake thermal efficiency,Compression ratio, Electrolyte,Engine performance, Four Stroke SI engine, Fuel consumption, HHO gas.*

I. Introduction

The reserve of petroleum over the world is limited. Decreasing supplies of fossil fuels and steadily rising concentrations of atmospheric carbon dioxide concentrations and levels of atmospheric pollutants are some of major challenges to the modern society. The scientific community is addressing these problems by an attempt to replace fossil fuels with cleaner and renewable sources of energy [4]. Hydrogen gas is an example of a renewable energy source that can be used to partially supplement petrol fuel by enriching supply air. Advantages of introducing hydrogen gas include higher net heating value and diffusivity of hydrogen in air when compared to fossil fuels [5]. In addition, better diffusivity produces a much faster flame velocity that can lead to a better acceleration and torque output from the engine.

II. HHO Generation

HHO gas is a combinationofdaiatomic hydrogen and monatomic oxygen.. HHO gas is produced by a similar design of the electrolyzer that will split water into its various components [5]. Brown's gas has a plethora of unusual characteristics that seem to defy current chemistry [5]. The goal is to confirm claims of the Brown's gas and to help solidify the current theory of Brown's gas [5].

Electrolysis Process:

This isthe simplest methodofhydrogenproduction.Electrolyzers make hydrogen by passing an electric current through water containing an electrolyte as shown in Fig 1 [5]. The figure represents a schematic view of the HHO gas electrolyzer. The electromagnetic field changes the atomic structure of the hydrogen (H2) and oxygen (0) found in water from diatomic to monatomic [5]. In addition, the neutron bond holding H & 0 together releases [5]. As H & 0 separate, H is drawn to the positive and 0 to the negative terminal of the electrolyzer [5]. This is called disassociation. As the process continues, volume increases, and the H & 0 gas bubbles which stick to the fins of the electrolyzer become dislodged and float to the top [5]. As the monatomic hydrogen and oxygen gas bubbles break the surface of the water they recombine in the air space in the top of the electrolyzer as Brown's gas [5].

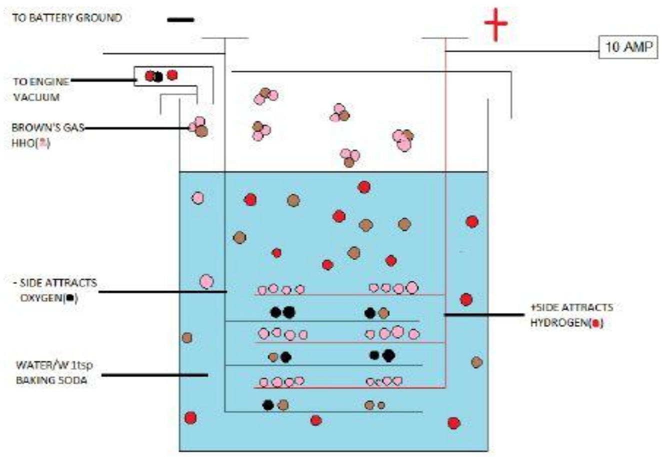

Figure 1 Schematic of Brown's Gas Electrolyzer[5]

III. Experimental Setup And Procedure

The setup consists of four strokes, single cylinder and water cooled petrol engine. The engine is coupled to eddy current type dynamometer for loading. The compression ratio can be varied without stopping the engine. Set up are provided with necessary instruments fuel flow, load, air flow and temperature measurements. It has stand alone panel box consisting of fuel measuring unit, fuel tank, manometer, fuel flow measurement, air box, transmitters for air. The cooling water is provided by Rotameter and measurement water flow by Calorimeter. A battery charger, battery, starter and is provided for engine electric start arrangement. The setup enables study of VCR engine performance for friction power, indicated power, indicated thermal efficiency, brake power, brake thermal efficiency, mechanical efficiency, specific fuel consumption and Air fuel ratio.

Figure 2 Experimental setup

Table 1 Technical specification of the engine

Parameter	**Details**
Make	Kirloskar Oil Engines
Engine	Four Stroke Single Cylinder, Water Cooled
Cylinder Bore	87.50 mm
Stroke Length	110 mm
Orifice diameter	20 mm
Dynamometer arm length	185 mm
Cubic Capacity (Cc)	661.45 cc
Maximum Power	4.5 Kw @1800 rpm
Speed Range	1200 to 1800 rpm
Connecting Rod Length	234 mm
Dynamometer	Eddy Current Type
CR Range	6:1 to 10:1

Table 2 Technical specification of HHO kit

Reactor Container Volume	2.5 liter
Electolyte	KOH
Electrode	Stainless steel plates
Voltage and current	12 V – 10 A

IV. Result And Discussion

- **Fuel Consumption**

The graphs 3 (a), 3 (b) and 3 (c) shown the effect of HHO gas on petrol engine at different compression ratio it shown that the fuel consumption is decreased as the HHO gas induced in cylinder.

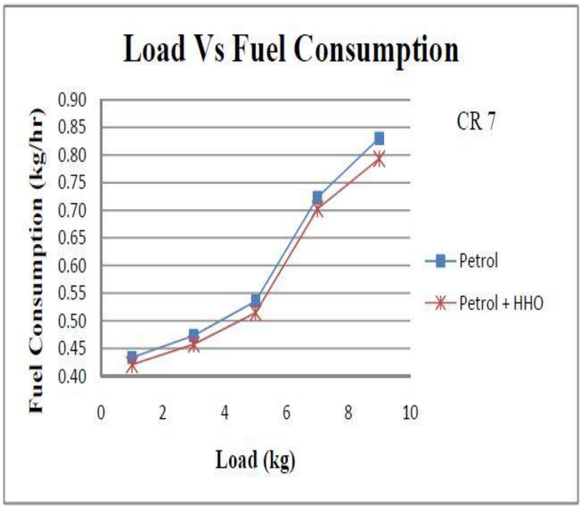

Fig. 3(a) Load Vs Fuel Consumption at CR 7

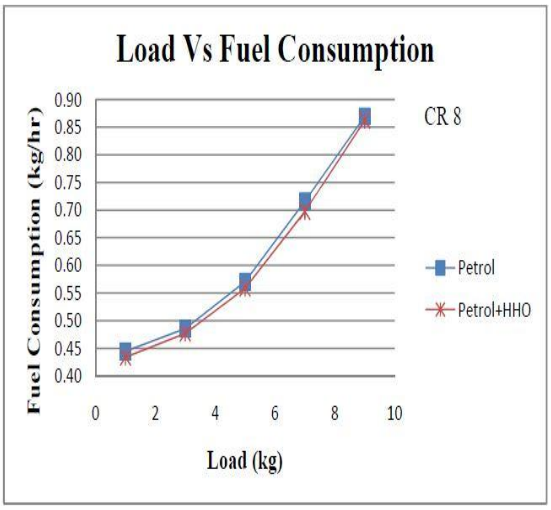

Fig. 3(b) Load Vs Fuel Consumption at CR 8

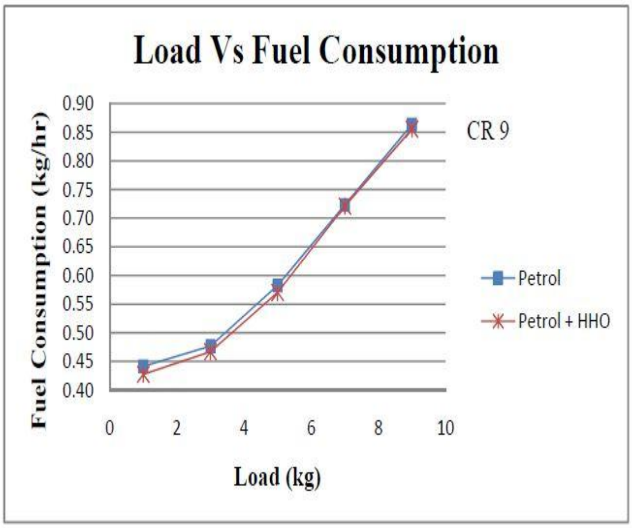

Fig. 3(c) Load Vs Fuel Consumption at CR 9

Figure 3(a) shows the effect on fuel consumption at different load (1, 3, 5, 7, 9 kg)at Compression ratio 7.
Figure 3(b) shows the effect on fuel consumption at different load (1, 3, 5, 7, 9 kg)atCompression ratio 8.
Figure 3(c) shows the effect on fuel consumption at different load (1, 3, 5, 7, 9 kg)at Compression ratio 9.

The fuel consumption increased when load increase in the both case at different compression ratio. When the HHO gas used in Petrol engine, fuel consumption decreased compare to Petrol engine.

Table 3 fuel consumption saving in percentage

Sr. no	Load (kg)	CR 7			CR 8			CR 9		
		t_{fp}	t_{fph}	Fuel Consumption saving %	t_{fp}	t_{fph}	Fuel Consumption saving %	t_{fp}	t_{fph}	Fuel Consumption saving %
1	1	61.95	63.85	3.07	60.40	61.90	2.48	60.85	62.82	3.24
2	3	56.75	58.70	3.44	55.30	56.30	1.81	56.35	57.50	2.04
3	5	50.15	52.20	4.09	47.08	48.08	2.12	46.10	47.09	2.15
4	7	37.12	38.24	3.02	37.50	38.50	2.67	37.15	37.25	0.27
5	9	32.33	33.85	4.70	30.89	31.15	0.84	31.10	31.40	0.96
Average time		47.66	49.368	3.58	46.234	47.186	2.06	46.31	47.212	1.95

t_{fp}=Time for 10ml of Petrol fuel consumption in sec
t_{fph}=Time for 10ml of Petrol + HHO fuel consumption in sec
% Decrease in fuel consumption for CR 7= [(49.368-47.66)/47.66*100 =3.58%
% Decrease in fuel consumption for CR 8= [(47.186-46.234)/46.234]*100 = 2.06%
% Decrease in fuel consumption for CR 9= [(47.212-46.31)/46.31]*100 = 1.95%
% saving in fuel is given in above table 3.

- **Indicated Thermal Efficiency**

Figure 4 (a), 4 (b), and 4 (c) shows the load Vs. indicated Efficiency graph which indicates the effect on indicated Efficiency at CR 7, 8 and 9 using HHO + Petrol.

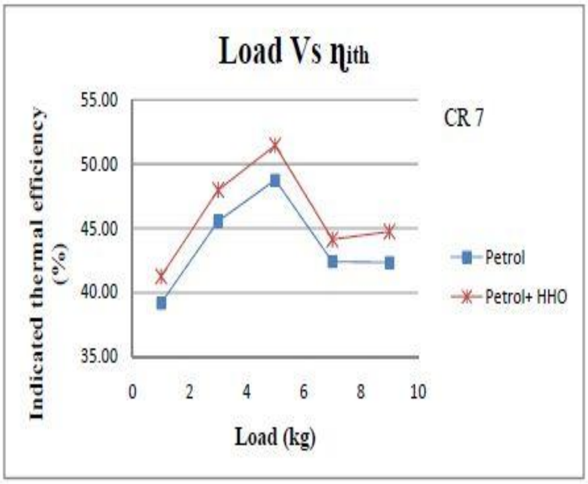

Fig.4(a) Load Vs Indicated Thermal Efficiency at CR 7

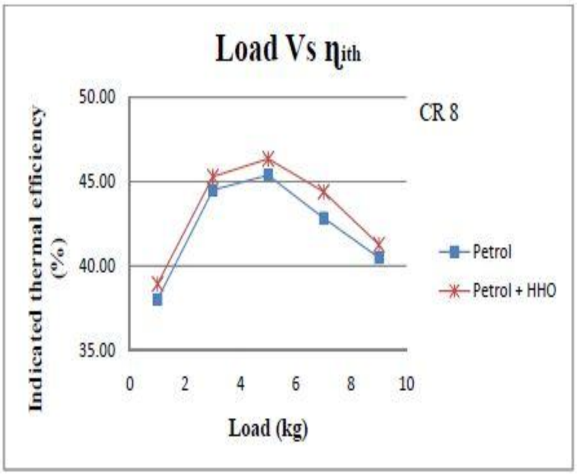

Fig.4(b) Load Vs Indicated Thermal Efficiency at CR 8

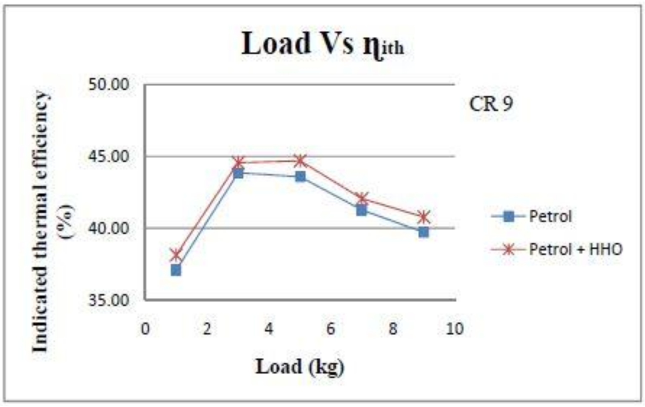

Fig.4(c) Load Vs Indicated Thermal Efficiency at CR 9

Figure 4(a) shows the effect on Indicated Thermal Efficiency at different load (1, 3, 5, 7, 9 kg)atCompression ratio 7

Figure 4(b) shows the effect on Indicated Thermal Efficiency at different load (1, 3, 5, 7, 9 kg) at Compression ratio 8.

Figure 4(c) shows the effect on Indicated Thermal Efficiency at different load (1, 3, 5, 7, 9 kg) at Compression ratio 9.

Indicated thermal efficiency increased in low load conditions and then decrease for Petrol engine and HHO + Petrol engine. When the HHO gas used in Petrol engine, indicated thermal efficiency inceased compare to Petrol engine.When the compression ratio increased 7 to 9, indicated thermal efficiency increased in low load conditions then after decreased using Petrol and HHO + Petrol.

- **Brake Thermal Efficiency**

Figure 5(a), 5(b) and 5(c) shows the load Vs Brake Thermal Efficiency graphs which indicate the effect on Brake Thermal Efficiency at Compression ratio 7, 8 and 9 for Petrol and HHO + Petrol.

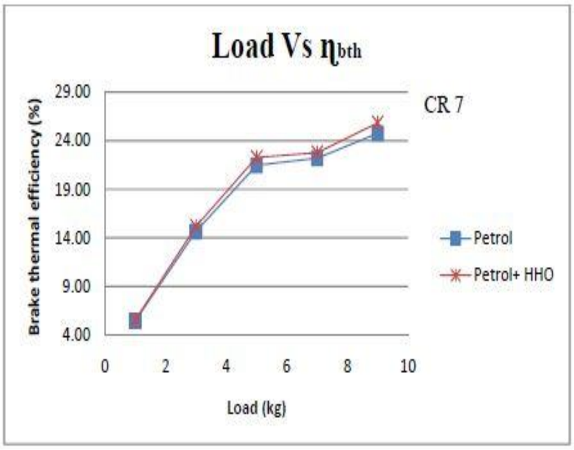

Fig.5(a) Load Vs Brake Thermal Efficiency at CR 7

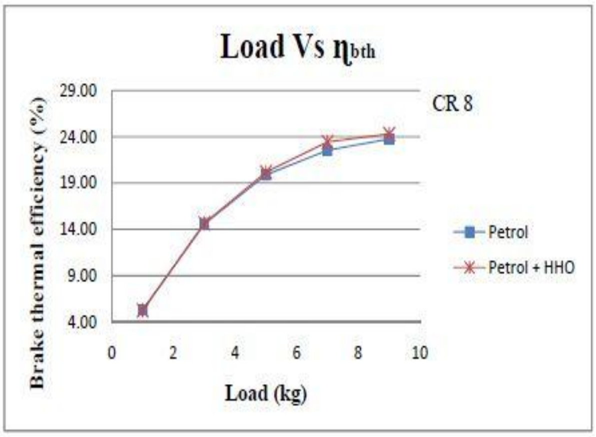

Fig. 5(b) Load Vs Brake Thermal Efficiency at CR 8

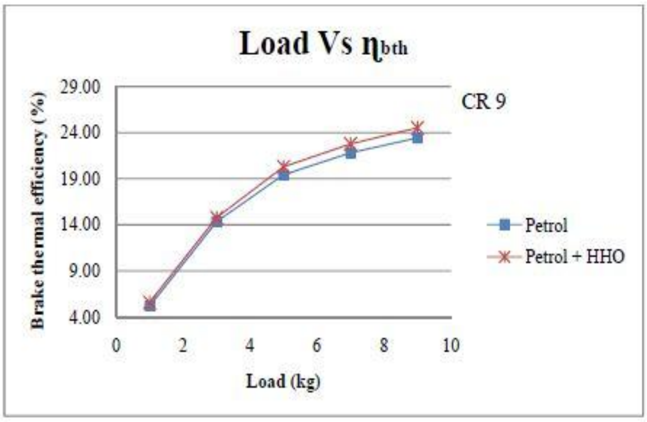

Fig.5(c)LoadVs Brake Thermal Efficiency at CR 9

Figure 5(a) shows the effect on Brake Thermal Efficiency at different load (1, 3, 5, 7, 9 kg) at Compression ratio 7.

Figure 5(b)shows the effect on Brake Thermal Efficiency at different load (1, 3, 5, 7, 9 kg) at Compression ratio 8.

Figure 5(c) shows the effect on Brake Thermal Efficiency at different load (1, 3, 5, 7, 9 kg) at Compression ratio 9.

The Brake Thermal Efficiency increased when load increases for Petrol engineand HHO + Petrol engine. Brake thermal efficiency indicates the fraction of heat supplied that is transformed into engine shaft[5]. A Graph has shown the increase in the brake thermal efficiency for Petrol with HHO gas. It indicates that the engine performance increase by addition of HHO gas.

- **Mechanical Efficiency**

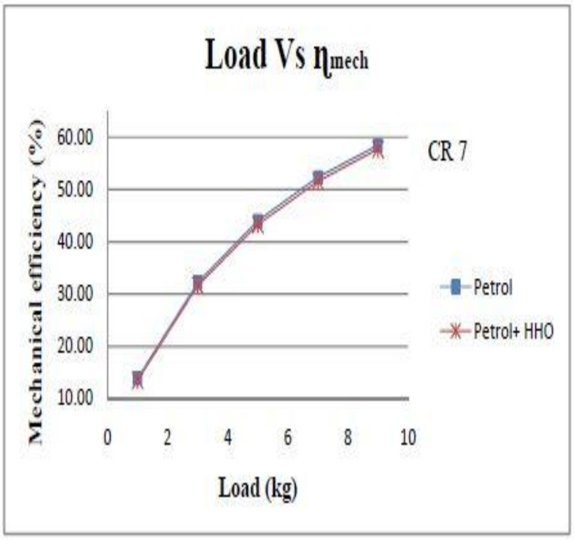

Fig. 6(a) Load Vs Mechanical Efficiency at CR 7

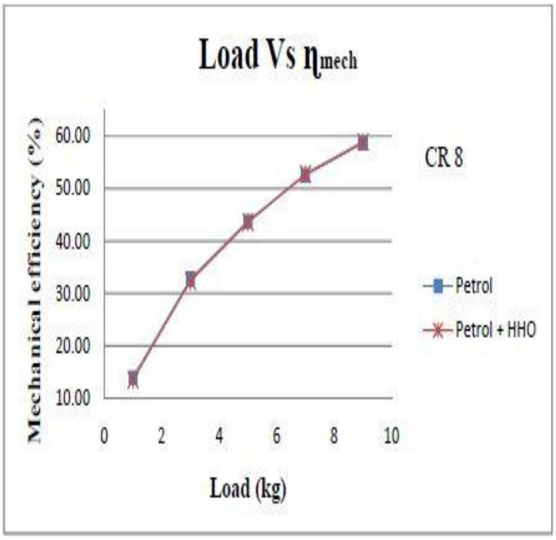

Fig. 6(b) Load Vs Mechanical Efficiency at CR 8

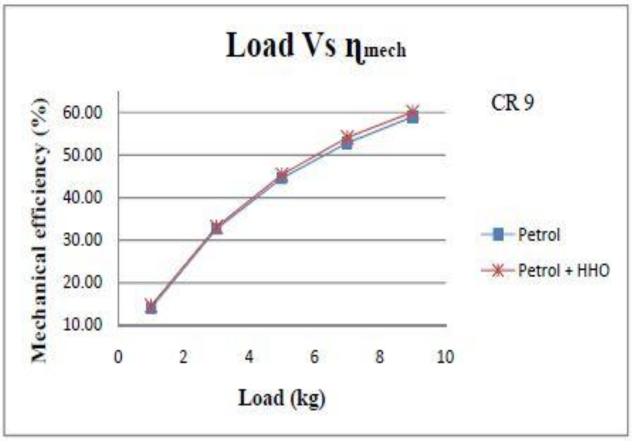

Fig. 6(c) Load Vs Mechanical Efficiency at CR 9

Figure 6(a) shows the effect on Mechanical Efficiency at different load (1, 3, 5, 7, 9 kg) at Compression ratio 7. Figure 6(b)shows the effect on Mechanical Efficiency at different load (1, 3, 5, 7, 9 kg) at Compression ratio 8. Figure 6(c) shows the effect on Mechanical Efficiency at different load (1, 3, 5, 7, 9 kg) at Compression ratio 9. Figure 6(a), 6(b), and 6(c) shows the load Vs. Mechanical Efficiency graph which indicates the effect on Mechanical Efficiency at CR 7, 8 and 9 using Petrol + HHO. Mechanical efficiency increased when load increases for Petrol engine and HHO + Petrol engine. As the graph 6(a) shown that load increased mechanical efficiency of the engine fuelled with Petrol + HHO give poor results of performance.As the graph 6(b) shown that load increased mechanical efficiency of Petrol engine as well as HHO + Petrol engine.As the graph 6(c) shown that mechanical efficiency of HHO + Petrol engine given better performance compared to Petrol engine

V. Conclusion

Experimental investigation of the effect of HHO gas on the performance test on 661 cc single cylinder spark ignition engine carried out. From experiment work the following conclusions are made:

- The use of 2.57 %, 2.60% and 2.74 % HHO gas in Petrol engine at different compression ratio (7, 8, 9) reduce fuel consumption by 3.58 %, 2.06 and 1.95 % respectively.
- Use the 2.57%, 2.60% and 2.74 % HHO gas in Petrol engine brake thermal efficiency of engine increase around 0.61%, 0.34% and 0.74 at compression ratio (7,8,9) respectively.
- When compression ratio increased, the % of HHO gas also increased with CR. There for the effect of both these parameters, occurs on mechanical efficiency. The mechanical efficiency increase with increasing the compression ratio and % of HHO.

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