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An Experimental Investigation of HHO Gas and Varying Compression Ratio on Performance Characteristics of Constant Speed Diesel Engine

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***Abstract**: Petroleum based fuels are more in demand in the world. Fossil fuels are available in limited reserves. Nowadays, more researchers focus on protecting the environment and maintain the greenhouse effect. So, in this study,we use the hydrogen gas with diesel fuel in CI engine. Many processes and methods of hydrogen production are found by researchers. Some processes are not economical so, in this paper use the cheaper method of hydrogen production which is electrolysis process. TheHHO gas was produced by the process of water electrolysis. Hydroxy gas was produced by the electrolysis process of different electrolytes with various electrode designs in a hydrogen generator. In this experiment hydrogen use at a constant flow rate in CI engine. This paper presents the concern with the HHO gas addition on performance and combustion characteristics of a Constant speed CI engine with variable compression ratio like that 16, 17 and 18 and variable load like that 1, 3, 5, 7and 9. The effect will be shown on the graphs of CI engine for the brake thermal efficiency, indicated thermal efficiency, mechanical efficiency and fuel consumption with the use of HHO and a variable compression ratio at 16, 17 and 18 and variable load like that 1, 3, 5, 7and 9.*

***Key words:** CI engine, Compression ratio, electrolysis, Electrolyte,HHO gas, Performance characteristics*

I. Introduction

Faced with the ever increasing cost of conventional fossil fuels, researches worldwide are working overtime to cost effectively improve internal combustion engine (ICE) fuel economy and performance characteristics. In recent years, many researchers have focused on the study of alternative fuels which benefit enhancing the engine economic and performance characteristics.[1]The advantages of using hydrogen as fuel for internal combustion engine is among other a long-term renewable and less polluting fuel, non-toxic, odorless, and has wide range flammability. Other hydrogen properties that would be a challenge to solve when using it for internal combustion engine fuel, i.e.: low ignition energy, small quenching distance, and low density. The diesel-hydrogen dual fuel engine can be operated with less fuel than neat diesel operations, resulting in reduce fuel consumption. [4]Compare to other kinds of fuel around the world, water is one of the free recourses and by applying the technique, it can be converted into hydrogen with oxygen, its chemical term is HHO and in general “Free Energy”. It is cheaper, safer, tremendous explosive and never pollutes the atmosphere. While crossing a gas or diesel operated car we can feel the smell of the respective fuels, it shows that the fuel is not completely burnt. It is explicit that we waste fuel and pollute the atmosphere. To avoid these drawbacks, some level of HHO is mixed with filtered air, which is after the air filter system and before the engine in taken system of the car. This mixed HHO ignites releasing the extra electrons into the igniting fuel and thus the added extra energy from the HHO leads cent percent of complete burning of the fuel. [5]

II. HHO Production

The hydrogen (HHO) was produced by the electrolysis process of differentelectrolytes with various electrode designs in a leak proof hydrogen generator. Among all fuels, hydrogen is a long term renewable, recyclable and non-polluting fuel. Hydrogen has some particular features compared to hydrocarbon fuels, the most significant being the absence of carbon. Very high burning velocity yields very rapid combustion and the wide flammability limit of hydrogen. [1]So at this time electrolysis process is most popular in the world which is given below:

Electrolysis Process

Thisisthe simplest methodof hydrogenproduction. Itispreferredwhencheap electric power, amplewater isavailableandhighpurityhydrogenisdesired. The positive current positively charged the anodes which yielded the electrolysis reaction of the electrolytic solution and eventually released gaseous oxygen and hydrogen were generated which, in turn, surfaced at the top portion of reactor container. Electrical power that fed the electrodes was measured and it was observed that reaction field was the major factor that influenced the amount of hydroxy gas generated. [1]

$$H^+ + 2e^- \rightarrow H_2$$

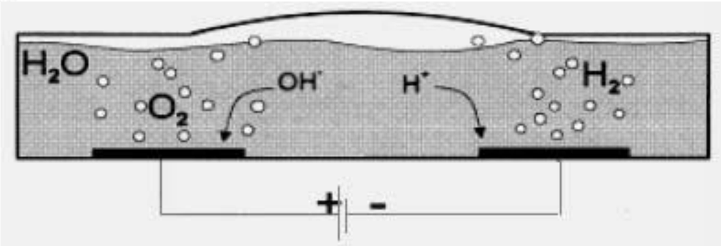

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Figure 1 Schematic explanation of the process of electrolysis[2]

Experiments on aqueous solutions of catalysts demonstrated that the HHO gas flow rate increased in relation to the mass fraction of catalyst in water. However, if the molality of NaOH in solution exceeded 1% by mass, the current supplied from battery increased dramatically due to the too much reduction of total electrical resistance. The plate electrode and NaOH were found the most efficient reactors and catalysts in relation to the electrical power consumed.[1]

III. Experimental Setup

The setup consists of single cylinder, four stroke, engine connected to eddy current type dynamometer for loading. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The setup has a stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and hardware interface. The Rotameters are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger is provides for the engine electric start arrangement. The setup enables study of VCR engine performance for brake power, indicated power, frictional power, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, and specific fuel consumption.[6]

[12]

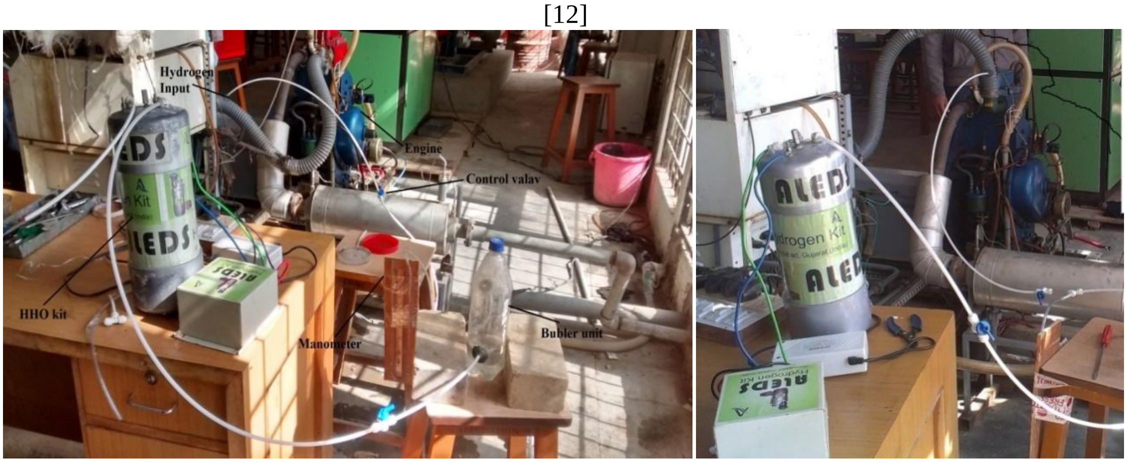


Figure 2 Experimental setup

Table 1 Technical specification of the engine.

No. of cylinder	Single cylinder
No. of stroke	4
Cylinder dia.	87.5 mm
Stroke length	110 mm
C.R. length	234 mm
Orifice dia.	20 mm
Dynamometer arm length	185 mm
Fuel	Diesel
Power	3.5 kW
Speed	1500 rpm
C.R. range	12:1 to 18:1
Inj. Point variation	0 to 25 BTDC

Table 2 Technical specification of HHO kit

Electrode (anode- cathode)	316L stainless steel plates
Voltage and current	12 V- 10 A
Electrolyte	NaOH
Reactor container volume	2.5 L

IV. Experimental Procedure

Experimental Procedure:

- Start the engine and wait for the steady state condition.
- Start the HHO kit and wait for hydrogen production and wait for steady state condition of it.
- After the steady state condition of engine, taken a reading for conventional diesel for various compression ratios (16, 17 and 18) and loads (1, 3, 5, 7 and 9 kg).
- Now, hydrogen introducing with diesel and wait for the steady state condition and constant flow rate of hydrogen.
- Before starting the reading, engine must be reached at steady state condition for correct reading.
- And then take reading for various compression ratios (16, 17 and 18) with varying loads (1, 3, 5, 7 and 9 kg).
- Then, from the reading calculate the performance and plot the graphs.

V. Result And Discussion

1) Fuel Consumption

Figure 3, 4, and 5 shows the load Vs. fuel consumption graph which indicates the effect on fuel consumption at 16, 17 and 18 compression ratio.

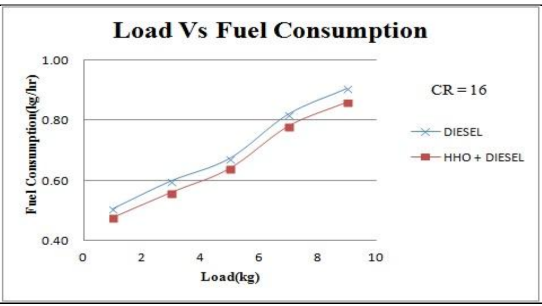


Fig. 3 Load Vs Fuel Consumption at CR 16

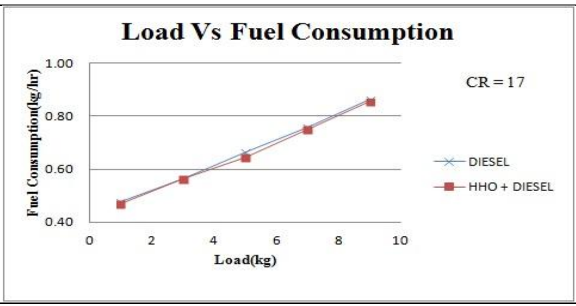


Fig. 4 Load Vs Fuel Consumption at CR 17

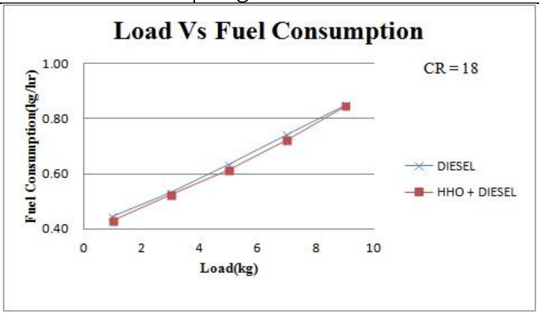


Fig. 5 Load Vs Fuel Consumption at CR 18

Figure 3, 4 and 5 shows the effect on fuel consumption at different load at 16, 17 and 18 compression ratio. As the load is increased, the fuel consumption increases in cases of diesel and HHO + diesel.

The Fuel consumption is decreased with respect to diesel engine when the HHO gas is introduced in diesel engines with constant flow rate**.**The Fuel Consumption is decreased when introduce the HHO gas in engine. As HHO gas is introduce in combustion chamber it takes part in combustion process delivering tremendous amount of energy the calorific value of HHO gas is way above the calorific value of diesel. The energy librated during the combustion of HHO and diesel is utilized in generating power from engine.

This is a constant speed engine the increment in speed is seen but due to self governing process governor will reduce the amount of diesel in combustion process to maintain the constant speed and decrement in fuel consumption is seen.The graph shows that as the compression ratio is increased, the fuel consumption is decreased this result is also seen in diesel + HHO gas.

Table 3 % savingFuel at Compression ratio = 16

Sr. no	Load (kg)	Compression ratio = 16	%saving in fuel	
		Fuel Consumption(Diesel)(kg/hr)	Fuel Consumption(HHO)(kg/hr)	
1	1	0.51	0.48	5.89
2	3	0.60	0.56	6.46
3	5	0.67	0.64	5.05
4	7	0.82	0.78	4.92
5	9	0.91	0.86	5.10

Table 4 % saving Fuel at Compression ratio = 17

Sr. no	load (kg)	Compression ratio = 17		% saving in fuel
		Fuel Consumption(Diesel)(kg/hr)	Fuel Consumption(HHO)(kg/hr)	
1	1	0.48	0.47	1.62
2	3	0.56	0.56	0.36
3	5	0.66	0.65	2.78
4	7	0.76	0.75	0.85
5	9	0.86	0.85	1.00

Table 5 % saving Fuel at Compression ratio = 18

Sr. no	load (kg)	Compression ratio = 18		% saving in fuel
		Fuel Consumption(Diesel)(kg/hr)	Fuel Consumption(HHO)(kg/hr)	
1	1	0.44	0.43	3.41
2	3	0.53	0.52	1.08
3	5	0.63	0.62	2.93
4	7	0.74	0.72	2.53
5	9	0.85	0.85	0.39

% saving in fuel is given in above table 3, 4 and 5.

2) Indicated Thermal Efficiency

Figure 6, 7, and 8 shows the load Vs Indicated Thermal Efficiency graph which indicates the effect on Indicated Thermal Efficiency at 16, 17 and 18 compression ratio.

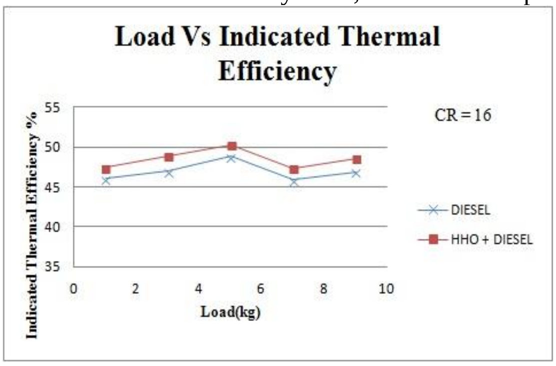


Fig. 6 Load Vs Indicated Thermal Efficiency at CR 16

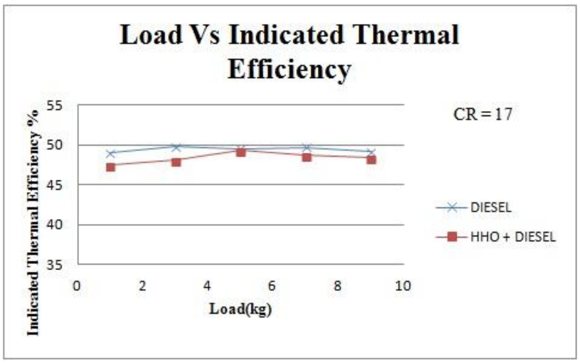


Fig. 7 Load Vs Indicated Thermal Efficiency at CR 17

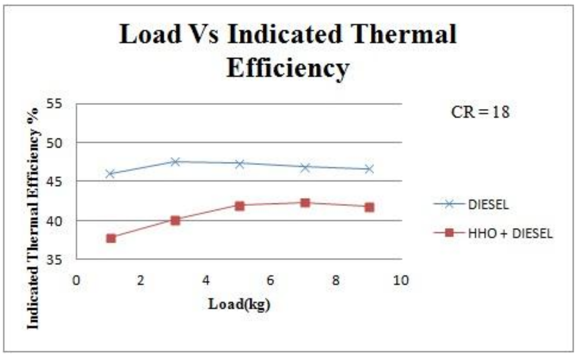


Fig. 8 Load Vs Indicated Thermal Efficiency at CR 18

The HHO gas was introduced in the diesel engine with constant flow rate, increase in Indicated Thermal Efficiency compared to diesel Engine and at CR=18 is decreased.

As the load was increased then seen the drastic change in indicated efficiency which is indicates on above graphs.

When CR is increases, decrement in fuel consumption is seen because of introduce the HHO gas.
As HHO gas is introduce the indicated thermal efficiency is increase as the fuel consumption of diesel is decreased.

3) Brake Thermal Efficiency

Figure 9, 10 and 11 shows the load Vs Brake Thermal Efficiency graphs which indicate the effect on Brake Thermal Efficiency at 16, 17 and 18 compression ratio.

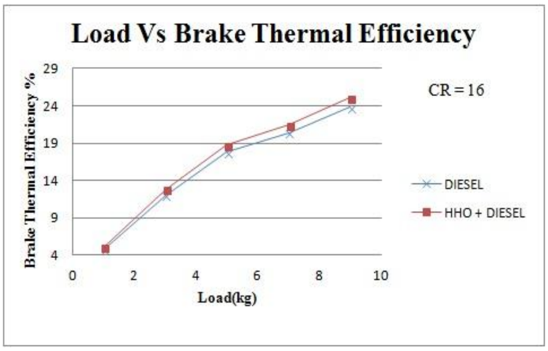


Fig. 9 Load Vs Brake Thermal Efficiency at CR 16

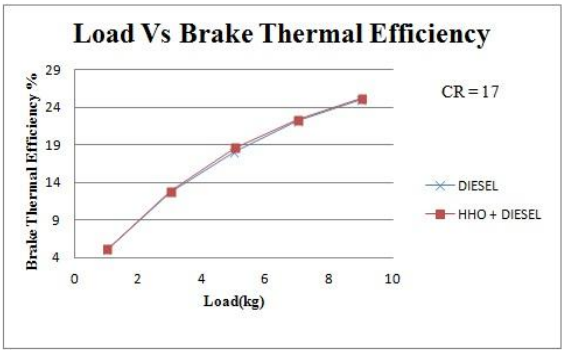


Fig. 10 Load Vs Brake Thermal Efficiency at CR 17

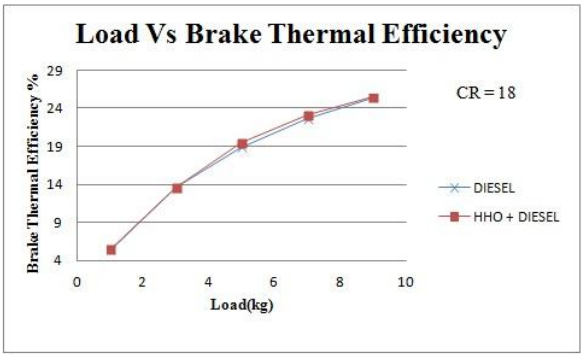


Fig. 11 Load Vs Brake Thermal Efficiency at CR 18

The HHO gas is introduced in the diesel engine with constant flow rate, at low load condition minor change in Brake Thermal Efficiency than some change is seen in Brake Thermal Efficiency at high load condition compare to diesel Engine at some specific compression ratio.

Brake Thermal Efficiency can be defined as the ratio between the brake power available at the crankshaft of the engine to the heat supplied given to the engine in the form of chemical energy available in the fuel.

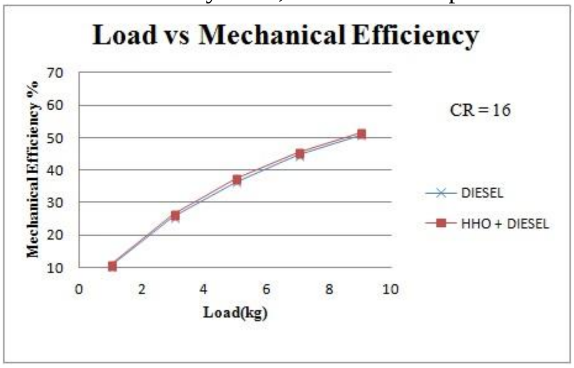
As HHO gas is introduce the brake thermal efficiency is increase as the fuel consumption of diesel is decreased.

Minor effect is seen of HHO gas on brake thermal efficiency, as compression ratio is increased.

No effect of HHO gas on brake thermal efficiency, as the compression ratio is increased.

4) Mechanical Efficiency

In Figure 12,13 and 14 shows the load Vs. Mechanical Efficiency graph which indicates the effect on Mechanical Efficiency at 16, 17 and 18 compression ratio.



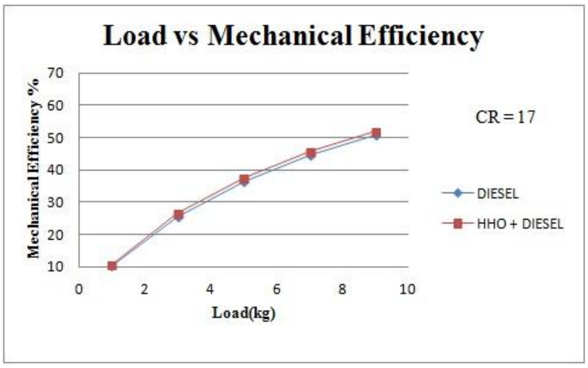


Fig. 12 Load Vs Mechanical Efficiency at CR 16Fig. 13 Load Vs Mechanical Efficiency at CR 17

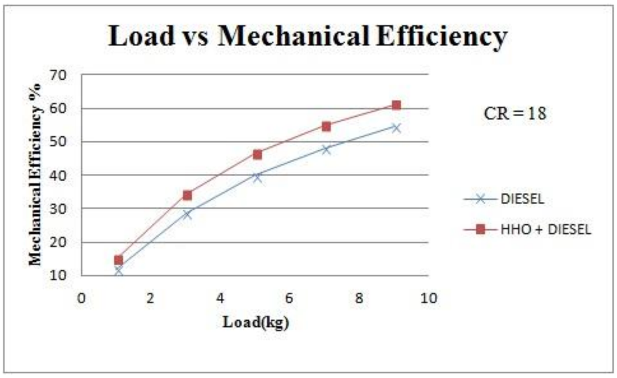


Fig. 14 Load Vs Mechanical Efficiency at CR 18

As the load is increased then the Mechanical Efficiency increases for diesel engine and HHO + diesel engine.

The HHO gas is introduced in the diesel engine with constant flow rate, in starting load condition, no change in Mechanical Efficiency than at high load condition drastic change is seen in Mechanical Efficiency compared to diesel Engine.

Mechanical efficiency is increased because of indicated power reduce with respect to brake power. As compression ratio increase, indicated power is reduced so, mechanical efficiency increase indirectly. At higher compression ratio, better mixing of HHO gas and diesel so, increase mechanical efficiency.

VI. Conclusion

The HHO gas is taken for experimental but it is secondary fuel, which could help in increase the performance of CI engine. Hear one experiment is conducted to know the combined effect of HHO gas and compression ratio on the performance of a diesel engine.

This experiment measures the effect of different compression ratio at 16, 17 and 18.

At compression ratio 16 the fuel consumption is decreasing and no drastic change is seen in SFC indicated thermal and mechanical efficiencies.

At compression ratio 17 no drastic change in SFC, Brake thermal efficiency and Mechanical efficiency, but minor change in FC and Indicated thermal efficiency.

At 18 compression ratio drastic change is seen in FC and better change in indicated thermal and mechanical efficiencies and no effect in SFC and Brake thermal efficiency with increasing in load.

So, hear conclude that compression ratio 18 is better to improve the engine performance

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