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Experimental Investigation of Diesel Engine Fuelled With Diesel and Hydrogen Gas at Different Compression Ratio

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Abstract
This research has been analysing effect of Compression Ratio (CR) on CI engine fuelled using Diesel and Diesel with Hydrogen gas. In this research performance parameters such as brake thermal efficiency and fuel consumption has been investigated. Experiments have been performed with different compression ratio (16, 17 and 18) with different load. In this investigation, the effect of Hydrogen additive gas on CI engine with different compression ratio has been analysed. The lower fuel consumption has been observed using Hydrogen as additive gas on CI engine with different compression ratio.
Keywords: *Diesel fuel and Hydrogen fuel, compression ratio, CI engine, performance*

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I. Introduction

The last few decades have been marked by milestones in technological development. Humans have developed systems and machines that make our lives easier [1]. Hydrogen can be used as a Hydrogen fuel for fuel cells or internal combustion engines. In 2020, major European companies announced plans to switch their truck fleets to Hydrogen power [2]. For many years, the IEA has monitored subsidies for fossil fuels, evaluating situations in which consumers pay less than the market price of the fuel itself. According to our preliminary estimates for 2022, oil subsidies increased by around 85% while natural gas and electricity consumption subsidies more than doubled. [3]. Also, Hydrogen is green energy which have 0% carbon emission it helps to reduce the carbon emission in environment. This study focuses on using Hydrogen gas as additive with Diesel fuel in Diesel engine. There are some researches are used Hydrogen as fuel in Diesel engine. **Bose and Maji** studied a 4-stroke, water-cooled, single cylinder Diesel engine and sent a quantity of 0.15 kg/h of Hydrogen in from the intake manifold via a solenoid valve. The 20%, 40%, 60% and 80% load conditions were tested [4]. **Liew et al.** observed the effect of Hydrogen on the combustion process as a function of the engine load and Hydrogen quantity for 4-stroke, 6-cylinder, heavy-duty Diesel engines [5]. **Bari and Esmail** observed the effect of a H_2/O_2 mixture generated by a water electrolyser at several quantities as a secondary fuel in a 4-cylinder, direct-injection, water-cooled Diesel engine at 19 kW, 22 kW and 28 kW loads. An increase of the brake thermal efficiency [6]. **Saravanan et al.** demonstrated that the addition of H_2 improved the brake thermal efficiency for the range of engine loads explored. The 2 different technique are used to observe the performance of CI engine carburation technique and timed port injection (TPI) technique. [7]. **Y. Karagoz et al.** examined effect of sending different rates of Hydrogen (0%, 16%, 36% and 46% H_2 of total fuel energy) on combustion, engine performance and emissions with single cylinder Diesel engine at full load condition (100% engine load), at 1300 rpm engine speed [8]. **Koten** used H_2 addition from intake port using 4 stroke 4 cylinder with DI Diesel engine with different amount of H_2(0.20,0.40,0.60,0.80 LPM) with different load (20%,40%,60%,80%,100%) it affects the BTE increase and the brake specific fuel consumption is decrease [9]. **Nag et al.** study combustion characteristics along with noise and vibration analysis of the Hydrogen-Diesel dual fuelled engine. The value of Hydrogen based on the energy share was varied in the sets of 0%, 5%, 10% and 20% [10]. **Santilli et al**. was studied that a new gaseous and combustible form of water the various measurements on a mixture of Hydrogen and oxygen called HHO gas produced via electrolyser which mixture is distinctly different than the brown and other known gases [11]. **Yilmaz et al.** was experimented that effect of hydroxy (HHO) gas addition on performance and exhaust emissions in compression ignition engines. H_2 gas was produced by using different electrolytes like KOH, NaOH, NaCl (among these, NaOH was specified as the most appropriate catalyst). [12].

II. Material And Method

Different properties of Diesel and Hydrogen additive gas shown in **Table 1**.

Table 1: properties of fuel used in experiment

Properties of fuel	Diesel	H_2 additive gas
Density	830 kg/m^3	1.2 kg/m^3
Calorific value	43000 kJ/kg	150000 kJ/kg
Carbon percentage	85%	0%
Auto ignition temp.	280 ˚C	585 ˚C

2.1 Hydrogen Flow Measurement Using Water Displacement Method:

The water displacement method can be used to measure the flow of Hydrogen gas in a pipeline. Here are the steps to follow. Water displacement method block diagram shown in **Figure 1**.

- Setup a container filled with water, such as a graduated cylinder or a burette.
- Connect the container to the pipeline using a valve and a tube. The tube should be inserted into the container so that it is submerged in the water.
- Open the valve to allow Hydrogen gas to flow through the pipeline and into the container.
- As the Hydrogen gas enters the container, it displaces an equal volume of water, causing the water level in the container to rise.
- Measure the volume of water displaced by the Hydrogen gas over a set period of time. In this experiment observed four reading and its reading shown in **Table 2**.
- Use the formula Q = V/t, where Q is the flow rate of Hydrogen gas in cubic meters per second, V is the volume of water displaced in cubic meters, and t is the time in seconds.
- Convert the flow rate to the desired units, such as cubic feet per minute.

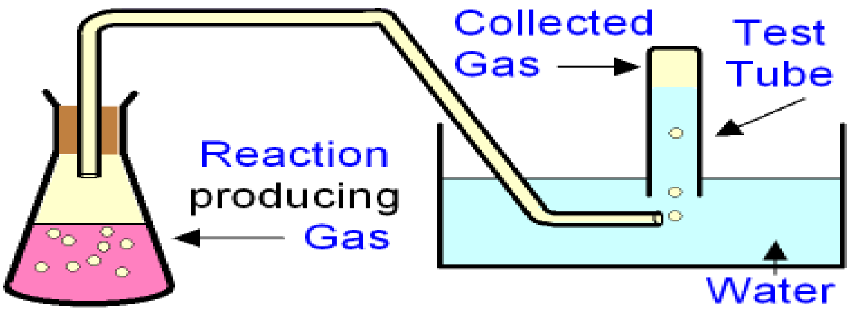

Figure 1: Water displacement method block diagram [13]

Table 2 shows data of experiment using water displacement method. This data shows at interval of 5cc how much time consumed for four different reading.

Table 2: Reading of water displacement method

CC / Sec.	5(ml)	10(ml)	15(ml)	20(ml)
1	54	103	170	232
2	63	98	154	204
3	52	114	183	216
4	50	108	166	255

III. Experimental Setup

The engine used for the experiment is a four-stroke water-cooled, single cylinder, direct injection, rated power of 3.5 kW at speed of 1600 rpm. Research engine connected to eddy current type dynamometer for loading. Specifications of the engine are given in **Table 3**.

Figure 2: Schematic diagram of 4-stroke single cylinder Diesel engine test rig [14].

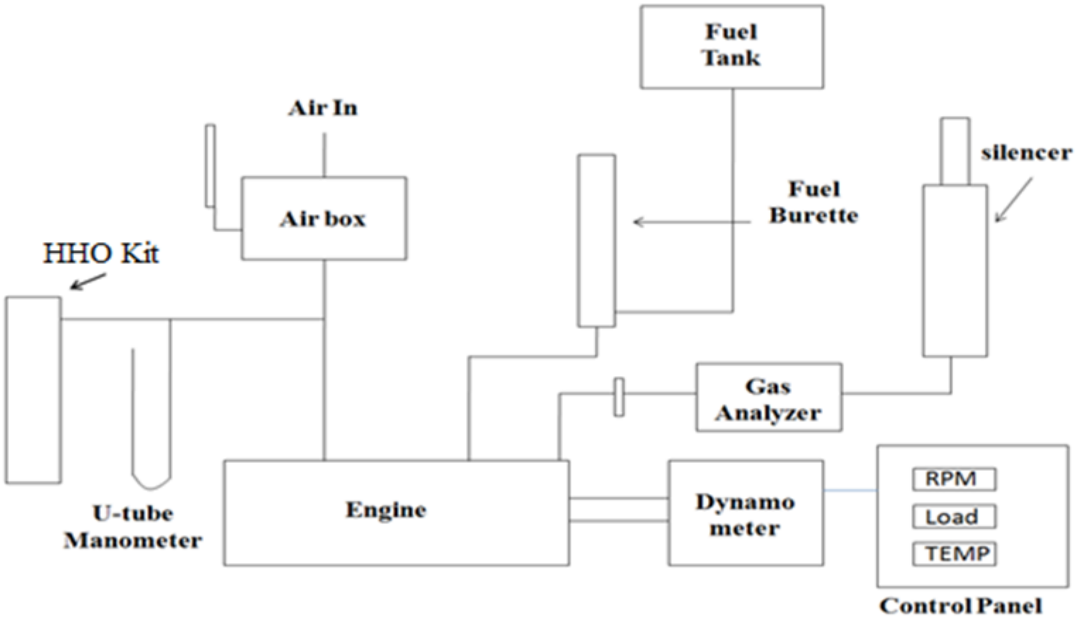

Table 3: Engine specification [15] [16]

Modal	TV1
Make	Kirloskar oil engines
Type	Four stroke single cylinder water cooled
No. of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Combustion principle	Compression ignition
Engine capacity	5.2 kW
Cubic capacity(cc)	0.661 L
778iPeak pressure	77.5 kg/cm^2
Direction of rotation	Clockwise (looking from flywheel end side)
Max. speed	2000 rpm
Min. idle speed	750 rpm
Min. operating speed	1200 rpm
Fuel timing for std engine	0 to 25 ˚BTDC

The experiment has been carried out on single cylinder, four stroke compression ignition engines [15] [16]. In first phase all experiments have been carried out at different compression ratio and different loading condition [15] [16]. In second phase same sets of experiment have been carried out on the same engine, when was fuelled with Diesel and Hydrogen as additive fuel.

IV. Result And Discussion

4.1 Effect of H_2 Gas on BTHE and Fuel Consumption at CR 16:

Figure 3 shows that variation of brake thermal efficiency with load of Diesel, Diesel with H_2 gas. In this investigation H_2 gas has inserted through air intake in Diesel engine with constant flow rate. **Figure 3** shows that at low load condition there was small change (0.1% increment) in brake thermal efficiency. At higher load, brake thermal efficiency (1.72% increment) was improved.

Figure 4 shows Diesel consumption with different engine load. Its observers that when Hydrogen gas used with Diesel, Diesel consumption was significantly decreased around 3.1%.

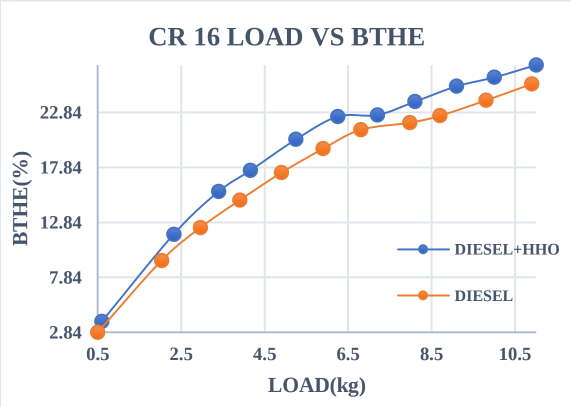

Figure 3: Load vs BTHE at CR 16

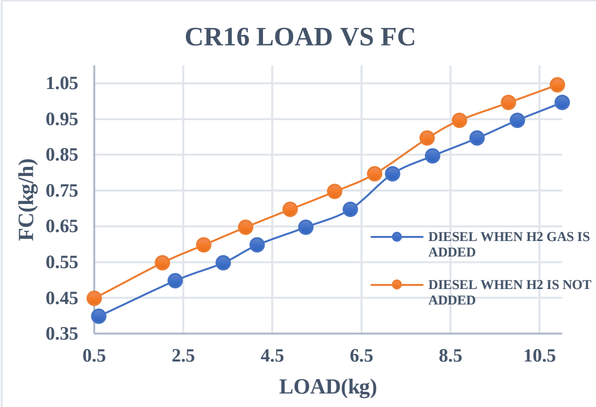

Figure 4: Load vs FC at CR 16

4.2 Effect of H_2 gas on BTHE and Fuel Consumption at CR 17:

Figure 5 shows Load vs BTHE graph at compression ratio 17. using H_2 gas with Diesel fuel load was increasing gradually. which give more accurate results for brake thermal efficiency. At initial stage brake thermal efficiency was increased by 0.45% and at final stage 2.33% brake thermal efficiency was increased as shown in figure.

It was observed from **Figure 6** that Diesel consumption was significantly decreased around 4.76%.

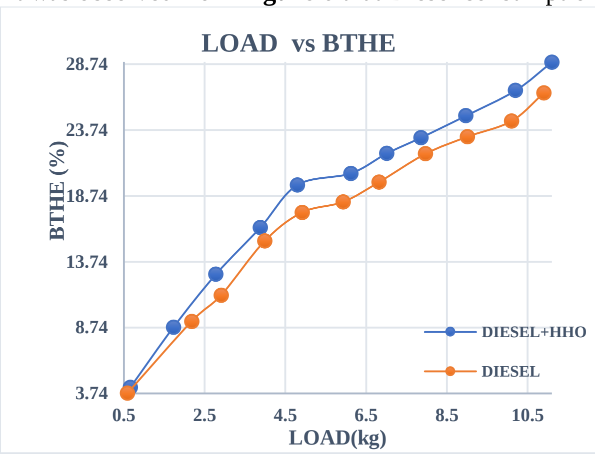

Figure 5: Load vs BTHE at CR 17

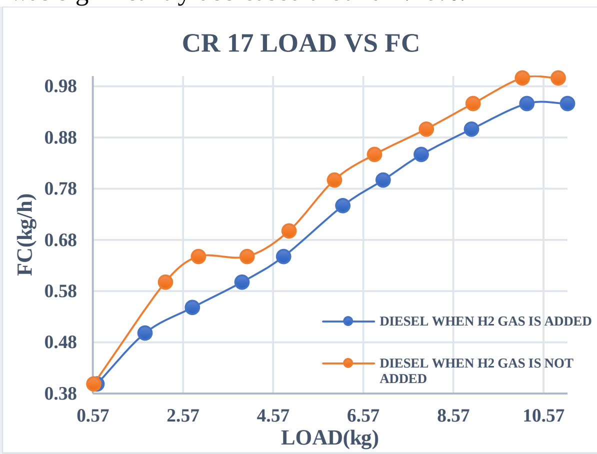

Figure 6: Load vs FC at CR 17

4.3 Effect of H_2 gas on BTHE and Fuel Consumption at CR 18:

Figure 7 shows Load vs BTHE graph at compression ratio 18. Using H_2 gas with Diesel fuel which give more accurate results for brake thermal efficiency. At initial stage brake thermal efficiency was increased by 0.9% and at final stage 1.43% brake thermal efficiency was increased as shown in figure.

It was observed from **Figure 8** that Diesel consumption was significantly decreased around 5.26%.

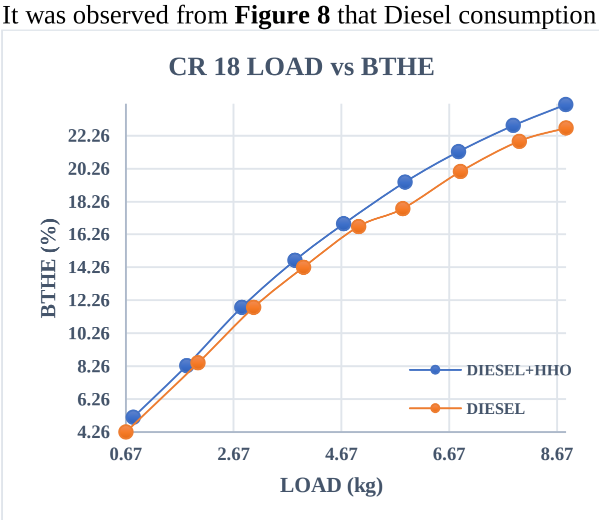

Figure 7: Load vs BTHE at CR 18

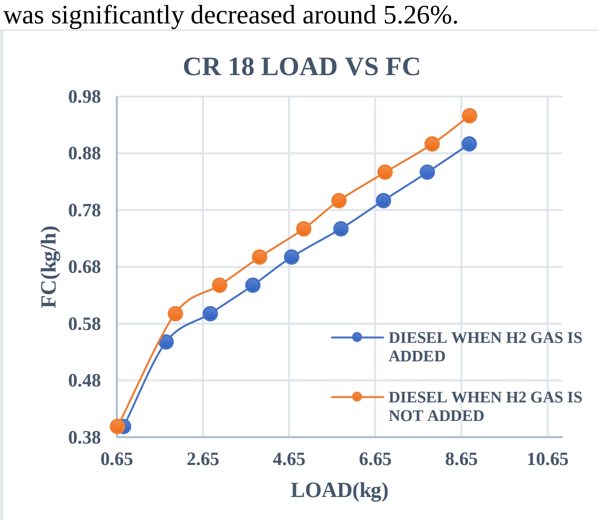

Figure 8: Load vs FC at CR 18

V. Conclusion

In this research the effect of H_2 gas has taken for experiment to study fuel consumption and brake thermal efficiency. This Experiment conducted to know the effect of H_2 gas and Diesel on CI engine with compression ratio 16, 17 and 18 with variation of load.

- At compression ratio 16, 17 and 18, fuel consumption has decreased and brake thermal efficiency was increased with different loads, it has observed that the fuel consumption has decreased using Diesel + Hydrogen gas as fuel compared to pure Diesel as a fuel.

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