PERFORMANCE OF DIESEL ENGINE BY ADDING SECONDARY FUEL AS HHO

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Abstract

From an environmental point of view, emission from the engine exhaust system is a serious problem. Alternative fuels are encouraged for this search. Hydroxy gas (HHO) is considered to be one of the secondary sustainable energy to meet the strict emission standards and maintain the greenhouse effect. Therefore, this paper experiment is carried out adding a secondary fuel hydrogen gas with diesel fuel in the CI engine. HHO is one of the best Choices that pertains to the fuel's complete combustion and thus also helps to reduce harmful gas emissions. The experiment is carried out on the 4-stroke, Single cylinder engine, using HHO for a diesel engine. At the engine inlet manifold, the HHO gas is supplied by the HHO kit. The HHO gas mixes with fuel, and enhances the process of combustion. The experimental investigation was performed for different HHO gas pressures, and the efficiency was evaluated and compared to pure diesel. The results show that HHO Performance at inlet pressure 3 kg/cm², Mechanical efficiency is increased by 5%, Brake thermal efficiency is increased by 7%, Specific fuel consumption is decreased by 0.0262 Kg/KWH, Volumetric efficiency is increased by 5.3% compared to pure diesel.

Keywords: Hydrogen, Alternate Fuel, Electrolysis, Electrodes, Fuel Consumption, Emission.

I. Introduction

Energy demands increased in modern days despite the growing world population. Energy demands from fossil fuels like natural gas and petroleum oils but fossil fuels have released poisonous gases during combustion and have negative environmental implications. Many research scientists are working on sustainable energy to control emissions and enhance vehicle performance [X]. From the many alternative fuels available the hydrogen gas, most research is under study. Some portion of Brown gas produced by the Electrolysis of water can be used to improve Lokanath M. et al
the performance of an I.C engine [XVI, XI]. The results justify that engine’s brake power and mechanical efficiency increased by 22% and 24% respectively by using KOH as catalyst with stainless steel electrodes in a leak proof Plexiglas reactor. Compared to engine operating with an HHO generator [VI], BSFC decreased by up to a maximum value of 35 per cent and 27 per cent respectively. HHO was produced by the electrolysis process of different electrolytes (KOH(aq), NaOH(aq), NaCl(aq)) with different electrode designs in a leak-proof Plexiglas reactor increased engine torque output of 19.1 per cent on average, a significant decrease in CO emissions of 13.5 per cent on average, HC emissions of 5 per cent on average and SFC emissions of 14 per cent on average [I]. To use a mixture of hydrogen supplement and diesel ignition method, it can achieve low-temperature combustion in which NO significantly reduces emissions. It affects the indicated, Brake thermal efficiency of the diesel engine [IV, VII, XIV and XV]. We can reduce CO, CO2 and NOx emissions using HHO in a transporter diesel engine. The engine performance improved reduced emission by using HHO gas at the operating condition of the engine [V, XII]. The confluence of its molecular composition and some of its unique properties. [XIII] It was shown that the use of high pressure hydrogen gas as a fuel in internal combustion engines has many economic advantages, such as better engine efficiency and reduced concentrations of emissions in exhaust gases. Experimentally discussed the hydrogen enriched air injection in a diesel engine system demonstrates that the specific fuel consumption decreased with hydrogen percentage increases over a diverse range of working conditions [VIII-IX].

II. HHO Technology

The HHO gas is also known as oxy hydrogen or brown gas formed from water electrolysis, where an electrical source is coupled with two membranes coupled with hydrogen and electrolyte. The attractive features of HHO gas are better combustion performance, readily availability, eco-friendly, rapid burning, and higher flame velocity. HHO gas is a mixture of hydrogen and oxygen gas, typically with an atomic ratio of 2:1 Hydrogen fuel enhancing to diesel in I.C Engine Improves the Fuel Efficiency and Power Output Of the engine.

II.i. Extraction of HHO from Water

In this paper, work on hydrogen gas is produced using an electrolysis process. For the decomposition of distilled water (H2O) into HHO an electrolytic cell is used. Because of this process of electrolysis, heat is released, so KOH / NaHCO3 can be gradually added to accelerate the excretion of H2O in HHO and to retain control of heat generation An electrical source is connected to two electrode platinum or stainless steel placed in the water. Hydrogen is established in a sufficiently designed cell at the cathode and oxygen occurs at the anode (a positively charged electrode). The reactions usually occur at the cathode. Splitting water with electricity to produce hydrogen and oxygen the chemical equation for electrolysis is:
II.ii. Characteristics of HHO

There is great promise for hydrogen to provide a clean safe and reliable energy source. Hydrogen is one of the most abundant energy sources in nature. Hydrogen and the internal combustion engine is an evolutionary approach to bridge the gap between current petroleum based technologies and the future using Hydrogen Fuel technologies as one of the primary sources of transportation.

II.iii. Need of HHO

In recent Studies researches have shown that HHO gas as secondary fuel addition to I.C Engines enhances the engine performance with less emissions of Exhaust gas due to the Depletion of the primary fuels as HHO is nontoxic.

II.iv. Advantages of HHO as Secondary Fuel

HHO Gas has the following advantages like, Ready availability, Gas nature-portability, Renewability, Higher heat content, Lower aromatic content less pollution

III. Experimental Setup

A single cylinder 4-stroke water-cooled diesel engine with a rated power of 5 HP at 1500 rpm was used for research purposes. The engine is coupled to an arrangement for the rope pulley brake to extract the heat generated. The fuel flow rate is measured using a burette and a stopwatch on a volumetric basis. Along with a digital temperature display, thermocouples were used to evaluate the exhaust gas temperatures of an engine. Air consumption is measured through the use of an M.S. A tank that is filled with a standard orifice and a U-tube manometer that estimates the pressure inside the tank. The setup enables the study of the performance of Diesel and with the addition of secondary fuel HHO at different pressure for different loads. The
engine parameters are BP, IP, FP, BMEP, IMEP, BTHE, volumetric efficiency, SFC are Computed.

Fig. 2: Experimental set up of 5 hp diesel engine

Table 1: Engine specifications

| Engine specifications | Kirloskar diesel engine |
|-----------------------|-------------------------|
| Speed                 | 1500 rpm                |
| Number of cylinders   | 1                       |
| Compression ratio     | 16.1                    |
| Orifice dia           | 20 mm                   |
| Maximum capacity      | 5 H.P                   |
| Stroke                | 110 mm                  |
| Bore                  | 80 mm                   |
| Type                  | Water Cooled            |
| Method of loading     | Rope brake              |

Fig. 3: Experimental setup
Table 2: Properties of hydrogen and diesel

| Properties                             | Units        | Diesel | Hydrogen |
|----------------------------------------|--------------|--------|----------|
| Ignition Temperature                   | K            | 530    | 858      |
| Minimum ignition energy                | mJ           | ------ | 0.02     |
| Flammability limits                    | volume % in air | 0.7-5 | 4-75     |
| Stoichiometric A/F ratio               | mass basis   | 14.5   | 34.3     |
| Limits of Flammability                 | equivalence ratio | ------ | 0.1-7.1 |
| Density at 16 °C and 1.01 bar          | KJ/m³        | 833-881 | 0.0838 |
| Heating value net                      | MJ/Kg        | 42.5   | 119.93   |
| Flame velocity                         | Cm/s         | 30     | 265-325  |
| Quenching gap                          | cm²          | ------ | 0.064    |
| Diffusivity gap                        | cm²/s        | ------ | 0.63     |
| Research octane number                 |              | 30     | 130      |
| Catenae number                         |              | 40-55  | ------    |

Fuel characteristics

III.i. Experimental Method

- Determine the peak load be applied to the engine.
- No load condition is ensured by controlling the supply of diesel, water circulation and lubrication oil in the sump.
- The engine started and permitted to run for a few minutes at a desirable rpm.
- The engine is conditioned progressively by a mechanical system of braking, and the speed is kept steady.
- Ensure that cooling water is delivered to the brake drum.
- Engine running in increments of 0%, 25%, 50%, 75% and 100% of peak load to be delivered.
- Note related observations of hanger weight, engine rpm, spring balance, fuel consumption (time of 10 CC), manometer reading and allow the engine to run for a few minutes before it stops.

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The same procedure is repeated for HHO fuel mixes at different inlets pressure of 0.5, 1,1.5,2,2.5 and 3kg/cm² pressure respectively.

III.ii. Calculations

1. Brake power=(π*(D_b+d)*(W-S)*N)/60000 Kw
   \[ D_b = \text{diameter of brake drum} = 0.36 \text{ m}, \ d = \text{dia of rope} = 0.012 \text{ m}, \]
   \[ N = \text{Speed of engine}, \ S = \text{spring balance reading} \]

1.1. Manometer reading =ΔH

1.2. Density of water= \( \rho = \frac{P}{RT} \)

1.3. Head of air column=h= (ΔH*1000)/100* \( \rho \)

1.4. Mass of air drum in to the cylinder = \( \text{m_{air}} = [C_d * A * (2gh)^{1/2} * 60] * \rho \) kg per min

Where

\[ C_d = \text{coefficient of discharge} = 0.62 \]
\[ A = \text{Area orifice} = \pi d^2/4 \]
\[ d = \text{Dia of orifice} \]
\[ H = \text{Manometer reading of air (meters)} \]

Measured fuel (20cc)* Sp.gravity*60*60

2. Total fuel consumption per hr (TFC) = \( \frac{\text{Brake power}}{\text{Time taken in second} \times 1000} \)

3. Indicated horse power (IHP) = BHP(Brake horse power)+FHP(Frictional horse power)

4. Actual discharge (Q_{act}) = C_d * A * (2gH)^{1/2} * 60 * \rho

Where

\[ C_d = \text{coefficient of discharge} = 0.65 \]
\[ A = \text{Area of section of orifice} = \pi d^2/4 \]
\[ d = \text{Diameter of orifice} = 0.02 \text{ m} \]

5. Mechanical Efficiency (\( \eta_{\text{mech}} \)) = BHP/IHP

6. Volumetric efficiency (\( \eta_{\text{vol}} \)) = \( \frac{Q_{act}}{Q_{the}} \) (or) \( \text{m}_{\text{air}} /((\pi/4 \times D^2 \times L \times N)\times k\times n \times \rho) \)

7. Brake thermal Efficiency (\( \eta_{\text{bthe}} \)) = IHP / (TFC * C.V)

8. Indicate thermal Efficiency (\( \eta_{\text{bthe}} \)) = BHP / (TFC * C.V)

IV. Results and Discussions

Experiments are performed using HHO gas as a Supplementary fuel in a single cylinder engine, four strokes without modifications to engine Specifications. Experimental data are obtained, investigated and evaluated for a 4-stroke single-

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cylinder, 5HP diesel engine Utilization of pure diesel and diesel+HHO blend at various inlet pressure conditions (0.5, 1, 1.5, 2, 2.5, 3 kg/cm²) and varying loads (0, 3, 6, 9, 12 Kg) by keeping constant speed at 1500 R.P.M. Distinctive parameters like Specific Fuel Consumption, Brake Power, Mechanical Efficiency, and Thermal Efficiency, Mass Flow rate, Volumetric Efficiency, Break Specific Fuel as various Load parameter was measured and promising test results were recorded.

IV.i. Specific Fuel Consumption and Load

The Graph plotted between load (kg) vs SFC (Kg/Kw.hr) for pure diesel and diesel+HHO at different inlet pressure. From the graph it has been concluded that the decline in SFC as load increases due to the uniform mixing of HHO with air as well as the oxygen inflation rate of HHO gas which assists diesel during the combustion process and delivers better combustion. By using Diesel+HHO gas at an inlet pressure of 3kg/cm² at a maximum load of 12 kg compared to pure diesel, an average reduction of 19% is achieved in SFC. Comparison between SFC with and without HHO generator coupling and the results in the above column graph demonstrates that significant change in the incorporation of HHO during the suction stroke.

IV.ii. Brake Horse Power and Load

The Graph plotted between load (kg) vs BHP (Kw) for pure diesel and diesel+HHO at different inlet pressure. From the graph it concluded that BHP improvement as load increases with and without coupling HHO generator. The result shows that 20.9% improvement is achieved in BHP by using Diesel+HHO gas at an inlet pressure of 3kg/cm² at a maximum load of 12 kg compared with pure diesel.

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IV.iii. Mechanical Efficiency Vs. Load

The Graph plotted between load (kg) vs Mechanical Efficiency (%) for pure diesel and diesel+HHO at different inlet pressure. From the graph it concluded that Mechanical Efficiency increases as load increases with and without coupling HHO generator. The Mechanical Efficiency at 12 kg for pure diesel 63.83%. And for Diesel+HHO are 52.21, 56.5%, 57.01%, 66.2%, 68.2% and 69.01%. The maximum increase in Mechanical Efficiency at 12 kg is 8.1% when compared with pure diesel and using Diesel+HHO gas at an inlet pressure of 3kg/cm$^2$.

IV.iv. Brake Thermal Efficiency Vs. Load

The Graph plotted between load (kg) vs Brake Thermal Efficiency (%) for pure diesel and diesel+HHO at different inlet pressure. From the graph it has been concluded that Brake Thermal Efficiency increases as the load increases with the addition of HHO. The maximum Brake Thermal Efficiency at a peak load of 12 kg is 52.8 per cent and Diesel+HHO gas at an inlet pressure of 3 kg / cm2 is 60.1 per cent. The percentage increase in Brake Thermal Efficiency is 13.8 per cent relative to Pure diesel.
Diesel and Diesel+HHO. It signifies the engine operates more consistently at constant load by incorporating an HHO generator.

**IV.v. Load Vs. Mechanical Efficiency and BHP & SFC**

The Graph plotted between Load Vs Mechanical efficiency, BHP & SFC Diesel+HHO gas at an inlet pressure of 3kg/cm² and compare the result with pure diesel with and without HHO in a single cylinder, four strokes but any modification to the engine. From the graph it concluded the result with pure diesel and diesel +HHO gas as supplementary fuel in a diesel engine. The Mechanical efficiency is increased by 8.12%, SFC is reduced by 19.1% ad BHP is increased by 20.01%.
V. Conclusion

The experimental investigation was performed out on a single-cylinder 4-stroke, 5HP diesel engine with varying inlet pressures of HHO gas using secondary diesel fuel, the performance was evaluated and compared to pure diesel. The following conclusion is surmised by comparison of the performance of pure diesel and HHO at an inlet pressure of 3 kg/cm$^2$ at a maximum load of 12 kg.

1. Specific fuel consumption is reduced by an average of 19 percent by the use of HHO gas.
2. Brake Horse Power increased by 20% using HHO gas at constant load using a dynamometer.
3. Mechanical efficiency is increased by up to 8.1 per cent at maximum load at a constant speed.
4. Brake Thermal efficiency is increased by 13.8% by the use of HHO gas.
5. The presence of oxyhydrogen gas through combustion drastically diminishes hydrocarbon emissions from Diesel engines.

Conflict of Interest:

No conflict of interest regarding this article.
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