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Performance Analysis 2000cc Gasoline Engine by Using Hydrogen-Pertamax Fuel Mixture

Ni Ketut Caturwati, Agung Sudrajad*, Putu Evan Raditya

Department of Mechanical Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon 42435, Indonesia.

*Corresponding author: agung@untirta.ac.id

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ABSTRACT

The use of motor vehicles has led to an increased demand for fossil energy sources as the main fuel and produce air pollution. Therefore, there is a need for alternative energy which is hydrogen. This research, we analyze the performance of a 2000cc gasoline engine with hydrogen as a mixture with Pertamax fuel, varying the engine speeds at 2000, 2500, 3000, and 3500 rpm. The variable of hydrogen flow rates at 0.6, 1.2, and 1.8 lpm. The experimental results obtained that the addition of hydrogen as a dual fuel have an impact on the increase in the alternator power output in 15% at the difference 0 lpm and 1.8 lpm of hydrogen flow rates. The thermal efficiency also increases with the addition of hydrogen reach to 10.46%. The specific fuel consumption shows decrease at 2000 rpm on 34% between 0 lpm and 1.8 lpm. The emissions of HC and CO were decrease, while CO_2 increases with the addition of hydrogen.

Keywords: *gasoline engine, hydrogen, thermal efficiency; fuel consumption; exhaust emission*

1. INTRODUCTION

Along with the advancement of the times, the use of motor vehicles has led to an increased demand for fossil energy sources as the main fuel. Not only because of its dwindling availability, fossil fuel also generates air pollution. Therefore, there is a need for alternative energy, one of which is hydrogen. Hydrogen as an alternative fuel has begun to be studied by various scientists. According to [1], hydrogen gas is a highly flammable substance, so when used in the combustion process, it can efficiently burn a mixture of fuel and air. According to [2], "hydrogen has unique characteristics that make it an ideal energy carrier."

The use of hydrogen as a dual fuel in gasoline engines could be a future solution for generating cleaner and more efficient energy. Hydrogen can be a very potential fuel due to its environmentally friendly properties, as its combustion can reduce carbon dioxide (CO_2) emissions, which is the main greenhouse gas. Integrating hydrogen into conventional gasoline engines offers advantages in reducing pollutant emissions such as carbon monoxide (CO) and hydrocarbons (HC), while also improving the thermal efficiency of the engine.

Several methods for injecting hydrogen into internal combustion engines are fuel carburetion method, inlet manifold method and direct injection method.

1.1 Fuel carburetion method

In hydrogen engines, the use of a gas carburetor, which is one of the oldest techniques. Since carburetors are often used in gasoline engines, the gasification process of hydrogen fuel can be simply utilized to convert widely used gasoline engines into hydrogen engines. The air-hydrogen mixture enters the intake manifold regularly. The valve regulates the amount of air that has been mixed with hydrogen, which powers the engine. Some machines require the addition of water.

Steam and air mixed with hydrogen are combined to enhance engine performance, especially at high speeds. This is determined by the amount of fuel that is taken in. Due to volumetric efficiency and lower system losses, engine power is reduced by up to 15%. This method can also lead to pre-ignition, knock, and engine pinging because the ratio remains constant.

1.2 Inlet manifold method

Hydrogen is delivered to the cylinder by mechanical or electric injectors that can operate at varying speeds and mix with the incoming air through the intake manifold. The intake manifold plays an important role. The unfavorable effects of the carburizing technique, such as shrinkage and shock formation, have been eliminated.

1.3 Direct injection method

The direct injection system forms a combination of air-fuel inside the combustion chamber after the intake valve closes, which is a more technically advanced mechanism. After compression, hydrogen is directly channeled into the combustion chamber, similar to what is achieved with various injection methods. Due to its rapid diffusion, hydrogen will quickly combine with air and can be used as an ignition source for spark plugs. Direct injection hydrogen engines outperform both other technologies in terms of performance and efficiency. Furthermore, in direct injection hydrogen engines, excessive automatic ignition temperature, increased pressure, and combustion delay can occur.

2. METHODOLOGY

The research experimental was conducted by testing a mixture of pertamax and hydrogen fuel on a 2.000 cc four-cylinder gasoline engine. The testing was carried out on an unloaded engine with varying engine speeds of 2000 rpm, 2500 rpm, 3000 rpm, and 3500 rpm, respectively. This research uses descriptive data analysis methods in graphical form, and then compared and analyzed for exhaust gas emissions in term of CO, HC, CO_2, and O_2 gases.

The image below shows the experimental setup that can be conducted in this research. In the picture, the components of the engine and the gas analyzer used in the measurement of exhaust gas emissions are showed. In this study, there are two variables that will be used: the independent variable, which in this research includes the engine speed used in data collection, specifically 2000 rpm, 2500 rpm, 3000 rpm, and 3500 rpm. In addition, there are variations of the flow rate of hydrogen fuel: pure pertamax (BE0%), 5% ethanol/95% 0 lpm, 0.6 lpm, 1.2 lpm and 1.8 lpm. The second is the dependent variable, which includes the exhaust gas emissions in the form of carbon gases CO, HC, and CO_2, as well as the thermal efficiency and fuel consumption used.

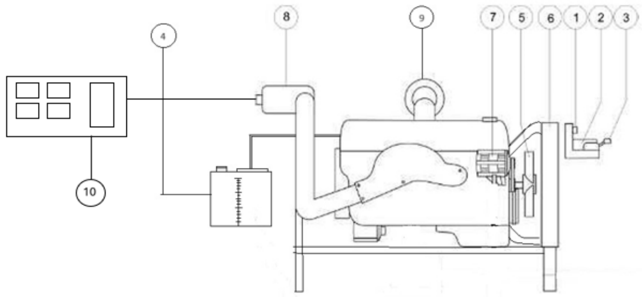

Figure 1. Experimental setup

Where:

1. Starting Engine
2. Speedometer
3. Throttle Control
4. Fuel Tank
5. Radiator Fan
6. Radiator
7. Alternator
8. *Exhaust*
9. Air Filter
10. Gas Analyzer

This test is conducted in 4-cylinder 2000 cc gasoline engine. The process of testing exhaust gas emissions is carried out by channeling some of the exhaust gas from the engine's exhaust. The exhaust gas is channeled using an iron pipe connected with a heat-resistant hose to convey the exhaust gas, which will later be tested for its emission values.

The process of collecting exhaust gas emission data will be carried out using the HESHBON HG-520 emission or gas analyzer. This tool is guaranteed to detect the gas content in the engine, such as carbon dioxide (CO_2), carbon monoxide (CO), and hydrocarbons. (HC).

3. RESULT AND DISCUSSION

The data on power output, specific fuel consumption thermal efficiency and emissions from the combustion of the tested diesel engine will be obtained.

3.1 Alternator power output

Alternator power output of experiment can calculate by using formula (1).

$$P = V\ X\ I \ \ldots\ldots\ldots\ldots \quad (1)$$

where:

P = Power (Watt)
V = Voltege (V)
I = Current (I)

After the calculations were performed, the alternator power value was obtained as shown in Table 1. It can be seen that the addition of hydrogen as a dual fuel, results in an increase in power output. At 2000 RPM, the values obtained at 0 lpm to 1.8 lpm were 263.8 watts, 274.4 watts, 296.671 watts, and 303.81 watts, respectively. The highest power value was achieved at 3500 rpm with an additional 1.8

lpm of hydrogen, resulting in an alternator power value of 327.275 watts.

Table 1. Alternator power

Daya Alternator (watt)				
RPM	0 LPM	0,6 LPM	1,2 LPM	1,8 LPM
2000	263,8	274,4	296,671	303,81
2500	275,4	298,161	311,696	314,925
3000	280,83	300,125	313,65	320,58
3500	287,87	306,25	316,2	327,275

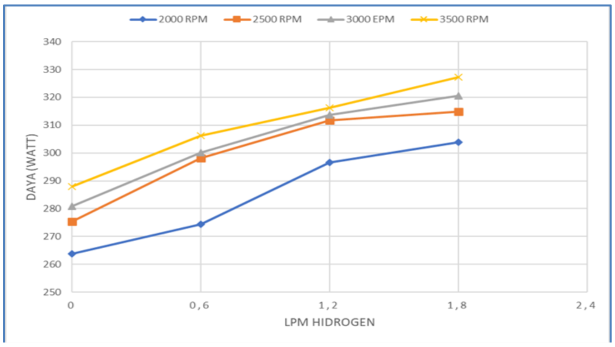

Figure 2. Graph of power output from alternator

Meanwhile, the highest percentage increase was observed in the comparison between the values at 2000 rpm between 0 lpm and 1.8 lpm of hydrogen, with values of 263.8 watts and 303.81 watts, resulting in an increase of 15%. The use of hydrogen as a dual fuel, which leads to an increase in the alternator power value, is due to hydrogen's ability to mix easily with the air in the combustion chamber, resulting in more complete combustion. Additionally, the difference in octane numbers between hydrogen and Pertamax can be a factor in increasing engine power across all rpm variations.

3.2 Specific fuel consumption (SFC)

The specific fuel consumption can measure by using flowmeter and calculate using formula (2)

$$SFC= \frac{m}{P} \text{.......................} \quad (2)$$

where:

SFC : Specific Fuel Consumption (kg/kWh)
m : Fuel mass flow rate
P : Alternator Power (kW)

The results obtained are shown in Table 2. The calculations shown in the graph indicate that specific fuel consumption decreased after hydrogen was added as a dual fuel. At 2000 rpm, the values obtained at 0 lpm to 1.8 lpm were 16.138 kg/kWh, 12.562 kg/kWh, 11.418 kg/kWh, and 10.646 kg/kWh, respectively. At 2500 rpm, the highest and lowest SFC values were 17.935 kg/kWh and 11.905 kg/kWh, respectively.

At 3000 rpm, the highest and lowest SFC values were 21.741 kg/kWh and 15.379 kg/kWh, respectively. Finally, at 3500 rpm, the highest and lowest SFC values were 22.685 kg/kWh and 16.517 kg/kWh, respectively. The highest percentage decrease in SFC occurred at 2000 rpm between 0 lpm and 1.8 lpm, with a decrease of 34%. According to existing journals, the reason for the decrease in SFC is that the mixing of hydrogen and air in the combustion chamber results in a more complete and faster combustion compared to Pertamax fuel, leading to a reduction in SFC.

Table 2. Specific fuel consumption (SFC)

SFC (Kg/kWh)				
RPM	0 LPM	0,6 LPM	1,2 LPM	1,8 LPM
2000	16,138	12,562	11,418	10,646
2500	17,935	13,651	12,520	11,905
3000	21,741	17,328	16,287	15,379
3500	22,685	19,944	18,138	16,517

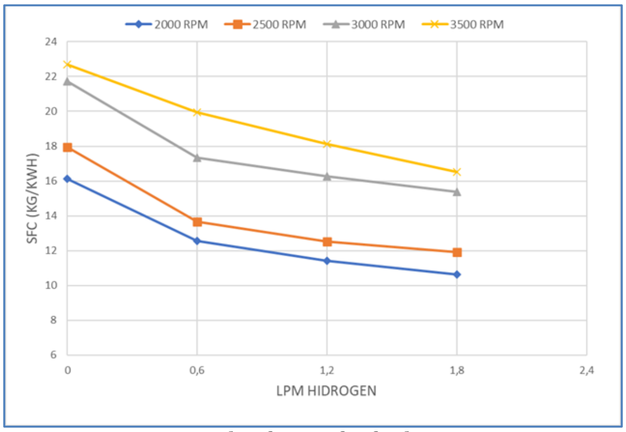

Figure 3. Graph of specific fuel consumption

3.3 Thermal efficiency

Results of calculation of thermal efficiency is using formula (3).

$$\eta th = \left(\frac{P}{(m_p \, x \, LHVp)+(m_{hyd} x \, LHVh)}\right) x \; 100\% \text{.....} \quad (3)$$

where:

ηth : Thermal efficiency (%)
P : Alternator power (kW)
m_p : Fuel mass flow rate pertamax (kg/h)
m_{hyd} : Fuel mass flow rate hydrogen (kg/h)
LHVp : Low heat value pertamax (kJ/kg)
LHVh : Low heat value hydrogen (kJ/kg)

In the calculation results, the thermal efficiency values at a variation of 2000 rpm were obtained at 0 lpm to 1.8 lpm, respectively, as 7.620%, 8.528%, 9.759%, and 10.45%. At 2500 rpm, the highest and lowest thermal efficiency values were recorded at 9.354% and 7.005%, respectively. At 3000 rpm, the highest and lowest thermal efficiency values were 7.245% and 5.134%, respectively. Finally, at 3500 rpm, the highest and lowest thermal efficiency values were 6.747% and 4.921%, respectively. The increase in thermal efficiency is due to hydrogen having a higher low heat value (LHV) than gasoline, with an LHV of around 119-120 MJ/Kg compared to Pertamax fuel with an LHV of around 43-44 MJ/Kg. This means that hydrogen produces a higher amount of combustion energy than Pertamax.

The low heat value (LHV) itself is the amount of energy produced from the combustion of a fuel without considering the energy contained in the water vapor formed during combustion. In addition, more complete combustion also contributes to an increase in efficiency values.

Table 3. Thermal efficiency

Efisiensi Thermal (%)				
RPM	0 LPM	0,6 LPM	1,2 LPM	1,8 LPM
2000	7,620	8,528	9,759	10,458
2500	7,005	8,170	8,902	9,354
3000	5,134	6,437	6,845	7,245
3500	4,921	5,593	6,147	6,747

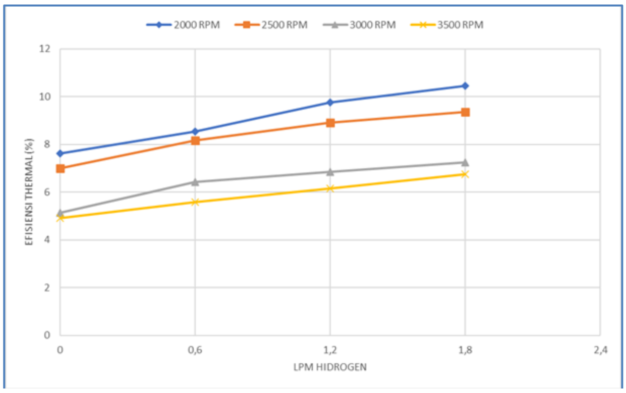

Figure 4. Graph of thermal efficiency

3.4 *Analysis of temperature, AFR, and exhaust gas emissions*

The following are the results of the exhaust gas temperature measured using a type K thermocouple as shown in Figure 5.

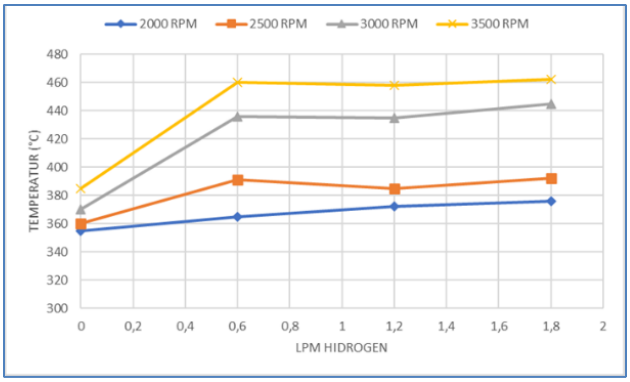

Figure 5. Graph of exhaust temperature

At a flow rate variation from 0 lpm to 1.8 lpm at 2000 rpm, the temperature values obtained were 355°C, 365°C, 372°C, and 376°C, respectively. At a flow rate variation from 0 lpm to 1.8 lpm at 2500 rpm, the temperature values obtained were 360°C, 391°C, 385°C, and 392°C, respectively. At a rotation speed of 3000 rpm, the temperature values obtained were 370°C, 436°C, 435°C, and 445°C, respectively. Finally, at a rotation speed of 3500 rpm, the temperature values obtained were 385°C, 460°C, 458°C, and 462°C, respectively. At 0.6 lpm, the highest temperature was at 3500 rpm with a temperature of 460°C, showing a percentage increase of 19.48%.

The highest increase occurred at 3000 rpm between 0 lpm and 1.8 lpm, with a percentage increase of 20.27%. Hydrogen itself is a flammable gas when mixed with air, when hydrogen and air combine in a combustion chamber, this can lead to an increase in temperature around the combustion space. In addition, continuous testing can be a significant factor in increasing temperature.

CO emissions

Hydrogen is a fuel that does not contain carbon in its molecular structure [3]. As an additional fuel, hydrogen helps achieve cleaner and more environmentally friendly combustion. The remaining CO emissions in the engine exhaust come from the combustion of lubricating oil and also from the combustion of Pertamax fuel.

Engines operating at 2000 rpm have lower CO emissions compared to those running at 3500 RPM. At 2000 rpm without the addition of hydrogen, the CO level is at 0.05, while with the addition of hydrogen at a flow rate of 1.2 lpm, it drops to 0.04, resulting in a reduction of CO levels by about 20%.

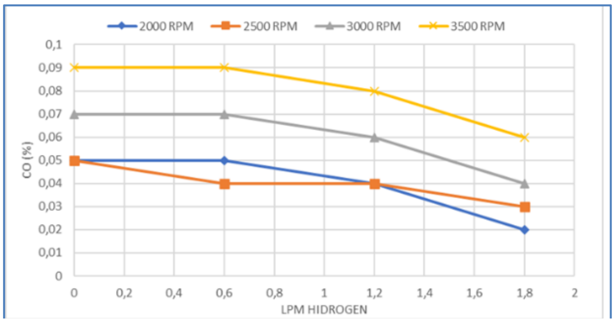

Figure 6. Graph of CO Emissions

HC Emissions

The use of hydrogen fuel as a dual fuel in combustion engines has an impact on the decreasing HC emissions. Hydrogen has a faster and more efficient combustion rate compared to Pertamax. The addition of hydrogen increases combustion efficiency within the engine cylinder, resulting in more fuel being burned completely. This can reduce HC emissions that come from unburned or partially burned fuel [10]. The largest percentage decrease occurred at the variation of 3500 rpm between 0 lpm and 1.8 lpm, with values of 2501 ppm and 2352 ppm respectively, resulting in a percentage decrease of 6%.

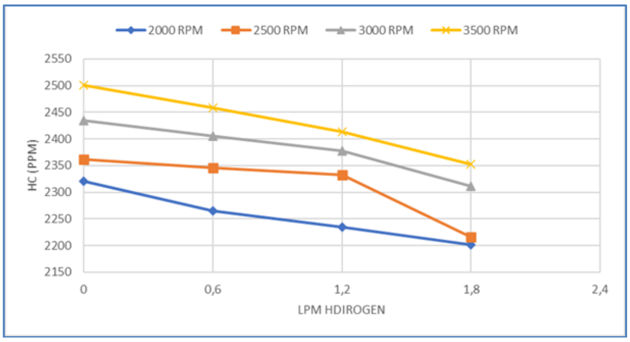

Figure 7. Graph of HC emissions

CO_2 Emissions

Although hydrogen itself does not contain carbon in its molecular structure, carbon is still produced from the residues of burning lubricating oil and Pertamax. The increase in combustion efficiency is marked by a rise in the carbon dioxide (CO_2) levels produced as the final result of complete combustion. The addition of hydrogen can enhance combustion efficiency, meaning that more fuel is burned completely. The largest increase in CO_2 levels occurred at variations of 2000 and 2500 rpm between 0 lpm and 1.8 lpm of hydrogen, with a percentage increase of 7%, and the highest CO_2 level recorded was 7.9% at 3500 rpm.

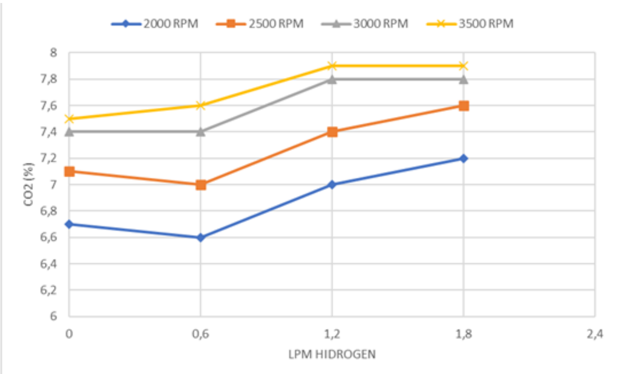

Figure 8. Graph of CO_2 Emissions

O_2 Emissions

The influence of the addition of hydrogen gas is seen in the decrease in O_2 levels. At a variation of 2000 rpm with the addition of hydrogen from 0 lpm to 1.8 lpm, the O_2 values obtained were 11.11%, 11.05%, 10.18%, and 9.89%, respectively. The lowest O_2 emission was recorded at a variation of 3500 rpm with the addition of 1.8 lpm of hydrogen at 8.76%, while the highest emission was recorded at 11.11% with 0 lpm of hydrogen and 2000 rpm. The percentage decrease in O_2 levels at 0 lpm and 1.8 lpm with an engine speed of 2000 rpm was 11%. The O_2 levels in the exhaust gas indicate the amount of oxygen that does not react with the fuel in the combustion chamber. The lower the O_2 levels, the better the combustion in vehicles.

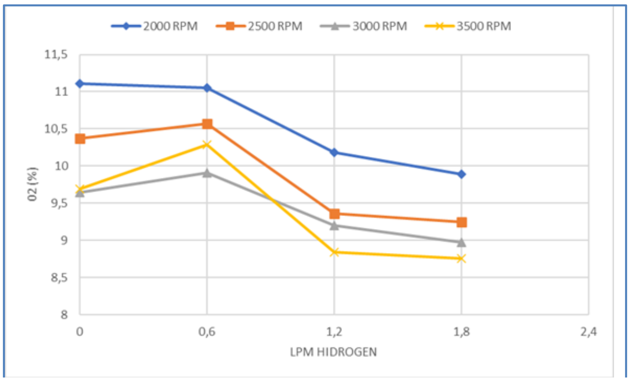

Figure 9. Graph of O_2 emissions

AFR (Air Fuel Ratio)

Based on the result, it can be seen that the addition of hydrogen affects the AFR value, where at 0 lpm and 2000 rpm, the AFR value is at 25.8. At 0 LPM and 2500 rpm, the AFR decreases to 24.3, then drops again at 3000 rpm to 22.9, and remains at 22.9 at 3500 rpm. The lowest AFR value is obtained at the variation of 3500 rpm with 1.8 lpm of hydrogen, with a value of 19.6, which is above the ideal or stoichiometric AFR value of 14.7:1.

The stoichiometric value of the Air-Fuel Ratio is the ideal ratio between the mass of air and the mass of fuel required to achieve complete combustion. In the tests, it was observed that the addition of hydrogen can affect the decrease in the AFR value. One of the factors contributing to this decrease is the reduction of oxygen levels in the combustion, which can be seen in the O_2 emission graph [12].

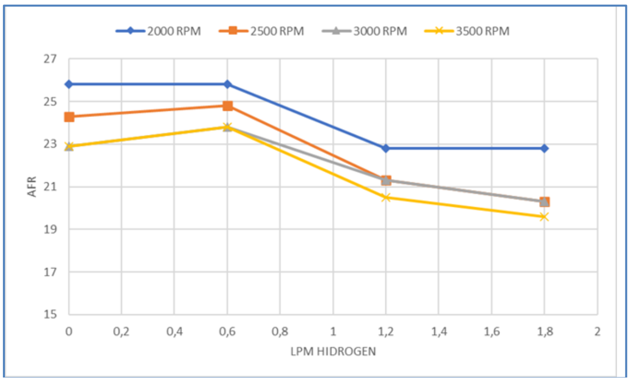

Figure 11. Graph of air fuel ratio

CONCLUSION

After conducting research and processing the test data, the following conclusions:

1. The addition of hydrogen as a dual fuel affects the increase in alternator power, which also leads to a constant increase in Alternator Power values along with the addition of hydrogen lpm. At a variation of 2000 rpm, the difference between 0

lpm and 1.8 lpm of hydrogen results in a 15% increase in Alternator Power. Similarly, the thermal efficiency also increases with the addition of hydrogen lpm with the highest efficiency value reaching 10.458%. The specific fuel consumption decreases with the increase in hydrogen flow rate in the intake manifold, where at 2000 rpm, the difference between 0 lpm and 1.8 lpm shows a 34% reduction in sfc.
2. The addition of hydrogen also affects the increase in exhaust gas temperature at 0.6 lpm, with the highest temperature occurring at 3500 rpm, reaching 460 °C, representing a percentage increase of 19.48%. The AFR value decreases, with the lowest recorded value at 3500 rpm with 1.8 lpm of hydrogen, measuring 19.6. CO emissions decrease with the addition of hydrogen, with the lowest CO value at 0.02%. HC emissions also decrease with the addition of hydrogen, showing a reduction of about 6%. The CO_2 level increases by 7%, while O_2 decreases by 11%.

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