

Isolating hydrogen from water for diesel engine

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Abstract This paper focuses on designing a hydrogen separator for water and developing a hydrogen production and distribution system for a 4-stroke Compression Ignition Engine (CIE) with a displacement of 2,500 cc and a constant engine speed of 1,100, 1,300, 1,500, and 1,700 RPM. STL 316L stainless steel sheets are used for both the hydrogen water separator and control tools. Each of the 3 channels consists of 3 sets, totaling 42 sheets with 14 poles, including 7 negative and 7 positive poles. The efficiency of hydrogen gas separation from water is measured, revealing that 1,100 RPM results in the highest fuel consumption rate. The average consumption rate of mixed hydrogen gas is 226 CC/min, compared to 325 CC/min for diesel fuel, resulting in a fuel savings of 99 CC/min. In comparison to the electricity used, the highest electric current is 14 A, with an average power of 163 W for electricity at a DC voltage of 12 V. The tests demonstrate that the engine utilizes the least amount of power (146.41 W) and consumes the least amount of fuel (99 CC/min) at 1,100 RPM. Based on these findings, it is determined that utilizing a hydrogen gas separation system from water mixed with diesel fuel could result in a 40% fuel savings.

Keywords: diesel engine, isolating hydrogen, water for diesel engine

1. Introduction

In the current environment, the quantity of fossil fuels is dwindling, while their prices are rising [1]. Therefore, humans are seeking alternative energy sources to replace fossil fuels, particularly natural energy such as solar energy, wind energy, gravity energy, and water energy. Water, a

vital resource for consumption, bathing, and various benefits, has a composition of (H₂O), consisting of 2 parts hydrogen (H) and 1 part oxygen (O) [2-3].

When water is supplied to the hydrogen water separator in line with electrical and chemical principles, a gas separation reaction occurs, separating

hydrogen gas as a combustible fuel from water. To achieve this separation for use as a co-fuel, scientists have developed and tested a hydrogen separator compatible with diesel, biodiesel, gasoline, LPG, and NGV for internal combustion engines.

Introducing hydrogen gas from the hydrogen separator into the intake manifold puts the engine in suction force mode, allowing air and hydrogen to be drawn into the combustion chamber. The combustion chamber of an internal combustion engine requires three components: fuel, air, and spark or compression [4]. H_2 gas becomes one of the fuels fired in the combustion chamber via the intake manifold, being a flammable gas.

Combining an electronic control unit (ECU) with a hydrogen water separator enables the engine to operate with reduced main fuel injection [5]. This aids in maintaining the primary fuel and, when mixed with it, completing combustion while simultaneously reducing emissions of pollutants and hazardous gases such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO), and particulate matter (PM2.5) [9].

Using the RPM signal, the ECU can control the production of hydrogen gas (H_2) to match the size and speed of the engine by adjusting the gas production as needed. The engine can transfer signals via the (H_2) ECU, reducing the system's electrical current needs (starting at only 1–10 Amp) [6].

Furthermore, to ensure safety, the system will automatically shut down if: the device exceeds specified electrical current

consumption; the battery current falls below the specified level; the equipment's temperature surpasses the specified limit; or if the engine fails to start. Additionally, the system may feature a backfire prevention mechanism, advanced temperature control in the gas separator to avoid excessive heat, and the incorporation of a water tank as a secondary raw material for hydrogen gas separation.

The goal of this study is to separate hydrogen gas (H_2) from water and use the resulting hydrogen gas as a co-fuel in an internal combustion engine (ICE) alongside the engine's main fuel. The electronic control unit (ECU) and the power control system, which control all operations electronically, ensure the safety of the hydrogen separation system. After the engine starts moving, the electronic system will control devices that prevent backfires and regulate hydrogen production to meet the engine's needs. As soon as the engine is turned off, the system ceases gas production and continues to store it as water.

The objective of this research was to extract hydrogen gas (H_2) from water and utilize the resultant hydrogen gas as a co-fuel, combining it with the primary fuel of an internal combustion engine (ICE). In the process, a compression ignition engine (CIE) was employed to directly separate hydrogen gas from water using a distinct electrical process without the need for storage in a separate tank.

This approach differs from those presented in other articles or experiments, as it primarily focuses on the separation of

hydrogen gas within industrial processes. The liquid is stored in a high-pressure tank while in a liquid hydrogen state, making the process significantly challenging and leading to prohibitively high production costs.

2. Technology of refuse-derive fuel

For the research and development of a system to separate hydrogen gas (H_2) from clean water and use it as fuel, mixed with the primary fuel of internal combustion engines, including both Compression Ignition Engine (CIE) and Spark Ignition Engine (SIE), the hydrogen separation system boasts a relatively high-security level. Every process is electronically controlled by a microcontroller or ECU. Hydrogen gas was blended with the primary fuel of internal combustion engines to serve as fuel. Subsequently, a power control system was equipped with a safety backfire mechanism and a method for regulating hydrogen production according to the engine's needs.

The acceleration of the engine is regulated by the electronic control unit (ECU). Once the engine stops, the gas separation system ceases gas generation and converts it to water. To reduce micro dust particles, the researcher investigated a

water-to-hydrogen separator for mixing with diesel engine fuel (PM 2.5).

The control of hydrogen gas separation can be effectively adjusted based on the engine's size and the electronic control unit's speed for producing gas using the engine's speed (RPM) through the electronic control unit (ECU). This results in lower electrical power consumption for hydrogen gas separation (between 1 and 10 amps) [2]. To prevent accidents, the system will automatically cut-off if: the system consumes an excessive amount of electrical power; the battery's power level decreases; the system's temperature surpasses normal limits; or if the engine has not yet started. Additionally, there is a gas distribution control system that adjusts to accommodate the size of each engine, a backfire prevention system, innovations in gas temperature control, and a water tank designed to contain spare resources for separating hydrogen gas production.

Fig. 1 illustrates the design of a device for separating hydrogen gas from water, the development of a system for producing and distributing hydrogen gas for use in both compression ignition engines (CIE) and spark ignition engines (SIE) as internal combustion engines, and the effects of hydrogen gas consumption on internal combustion engines and security systems.

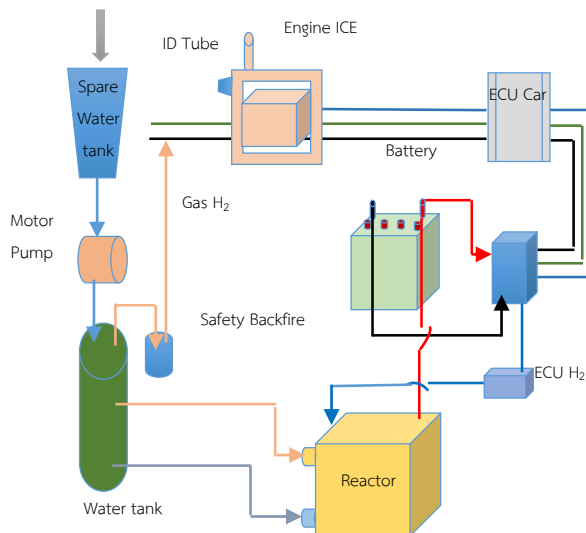


Fig.1 The design of the H₂ gas separation process and equipment.

The design of the hydrogen water separator included a device for separating hydrogen gas from water and a system for producing and distributing hydrogen gas for use in internal combustion engines, including both Compression Ignition Engines (CIE) and Spark Ignition Engines (SIE). The effects of hydrogen fuel gas on internal combustion engines and security systems were tested on vehicles with internal combustion engines, comprising both gasoline and diesel engines with a 4-stroke ignition type and a displacement ranging between 2,500 and 3,500 cc. An engine with displacement of 2,500 cc on a pick-up was equipped with a control system capable of adjusting the production of hydrogen gas based on the engine's rotational speed (RPM) or as required, to assist farmers in minimizing their production expenses; contribute to reducing air pollution small dust particles (PM 10 and

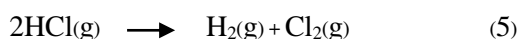
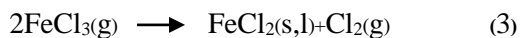
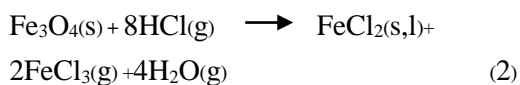
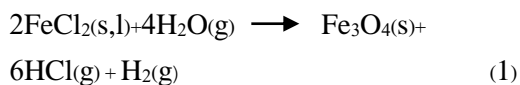
PM 2.5), and toxic gases due to improper combustion of internal engines.

3. Data Analysis

The objective of this research was to extract hydrogen gas (H₂) from water and use the resulting hydrogen gas as a co-fuel combined with the primary fuel of an internal combustion engine (ICE). The hydrogen separation system was a relatively secure system since all operations were electronically controlled by the electronic control unit (ECU) and power control system. Following engine acceleration, the electronic system will control backfire prevention devices and other devices to regulate the generation of hydrogen to meet the engine's requirements. When the engine was shut off, the system stopped producing gas and continued to store it as water.

The decomposition of at least two precursors [2] via catalytic chemisorption allows for the dissociation temperature.

(Dissociation Temperature) is lower for the dissolution of water. With catalysts obtaining molecules of many substances through indirect chemical reactions occurring at temperatures below 1,00 K, thereby reducing the limitations of the thermal decomposition processes using catalysts. Most are compounds of halogen elements (halogen), such as ferrous chloride (ferrous chloride, FeCl_2), calcium bromide (calcium bromide, CaBr_2), and magnesium iodide (gI_2). The main limitations of catalytic decomposition reactions in industrial or commercial applications are high production costs and efficiency. of low process



Direct current is applied to the electrodes of an electrochemical cell to release the ions in the electrolyte solution. It moves to react at the electrode, as stated by [4]. Chemical reactions occur as either oxidation or reduction reactions in a direction that cannot occur spontaneously without an electric current. The electric current must be greater than the standard volt for the reaction to occur. For example, the electrolysis of water requires volts higher than 1.229 volts to produce hydrogen

gas by hydrolysis. With electricity at the cathode, there is a reduction reaction of protons (hydrogen ions) in acidic conditions ($2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$), while in alkaline conditions, there is a reduction of water ($2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$) at The anode can be oxidized to produce oxygen gas ($\text{H}_2\text{O} \rightarrow \frac{1}{2}\text{O}_2 + 2\text{H}^+ + 2\text{e}^-$), as shown in Fig. 4 The advantage of hydrogen gas production from this method is its high purity. The disadvantage is the high cost of electricity.

4. Methodology

4.1 Design and Result

The system design for a hydrogen separator from water, intended for blending with the fuel of an engine with a capacity of 2,500 cc (a small set designed for engines with capacities of no more than 3,500 cc), has been prepared, along with a corresponding set of control equipment. Additionally, STL 316L stainless steel sheets were employed in three sets and three channels, resulting in a total of 42 sheets with 14 poles— 7 negative poles and 7 positive poles (Fig.2).

Hydrogen gas (H_2) is a vehicle fuel alternative to LPG and NGV/CNG that can be produced by installing a system that separates hydrogen from water. It creates hydrogen gas in the form of ready-to-use gas, eliminating the need for a gas storage tank. The system is simple to install, takes up little space, functions semi-automatically using a microcontroller as its controller, and generates hydrogen gas (H_2) from water for use as a co-fuel with gasoline, diesel, LPG,

and NGV. This study examined the fundamental ideas underlying the invention and development of hydrogen- powered automobiles, and therefore, a set of water-

hydrogen separators was acquired. It was used in an electrolysis process to produce hydrogen, which was subsequently mixed with fuel in an internal combustion engine.



Fig.2 Small hydrogen gas separator from water complied with 2,500 cc engine.



Fig.3 Isolating hydrogen from water for use in a diesel engine of 2500 cc.

As can be seen in Fig.4, the separated hydrogen gas was introduced through the intake manifold and burned with the oil in the combustion chamber of the internal combustion engine.

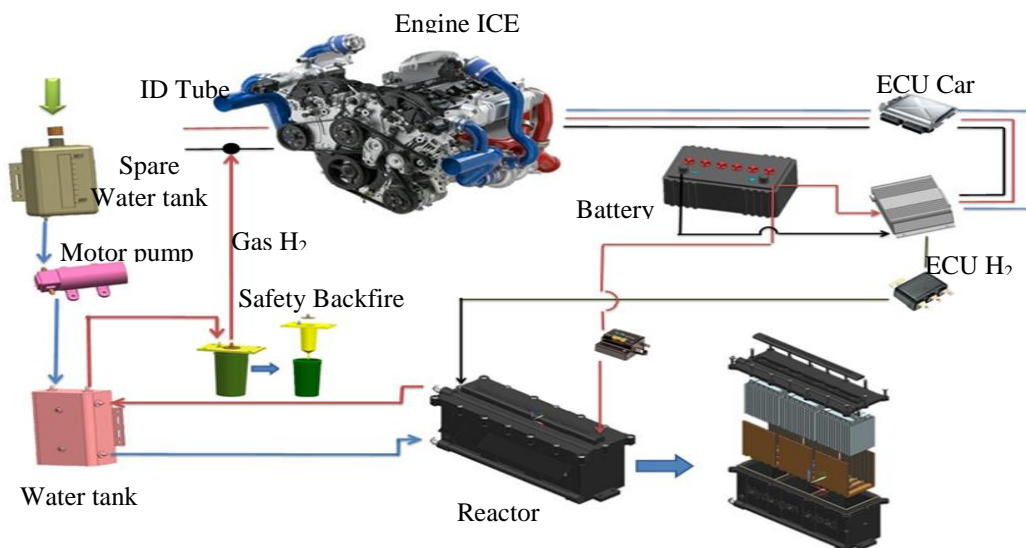


Fig.4 Hydrogen hybrid diagram.

The hydrogen separation system was a relatively secure system, as all operations were electronically controlled by the electronic control unit (ECU). The method employed involved adjusting the electrical contract to deliver less than the actual demand of the system and the power control system. After engine acceleration, the electronic system would control backfire prevention devices and devices regulating the generation of hydrogen to meet the engine's requirements. When the engine was shut off, the system ceased gas production and continued to store it as water.

This research incorporates a microcontroller system for separate process

control tailored to the engine's requirements. The system efficiently regulates both electric current and maintains a consistent engine speed, resulting in reduced fuel injection in the vehicle.

Additionally, it can be automatically shut off in the event of separator overheating or when the car's battery reaches critically low levels. The microcontroller issues a command for the separation system to immediately cease operation until all conditions return to normal, resuming continuous operation

there after. Notably, there is no other research where microcontroller controls are generated by directly utilizing both positive and negative electric currents, thus ensuring control over the aspects mentioned earlier.

Fig.5 illustrates the hydrogen control circuit, signal deception, or reduction in the equipment and sensors. This setup aims at diminishing the engine's oil consumption, with hydrogen subsequently added for compensation.

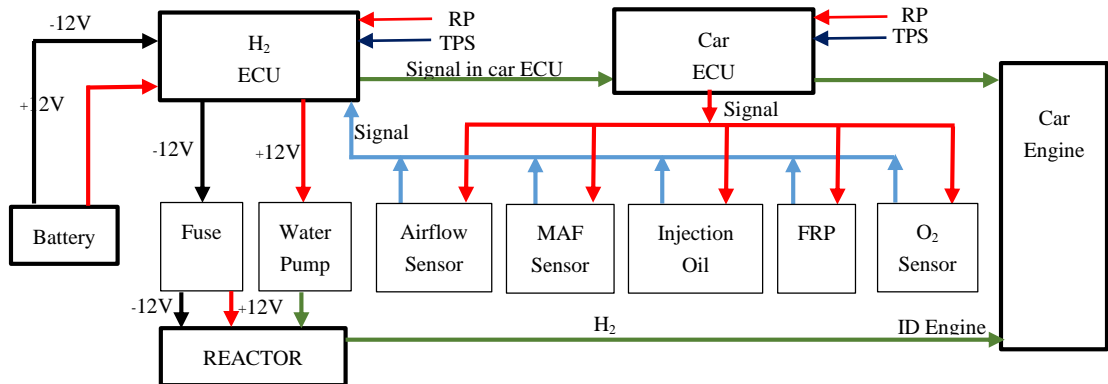


Fig.5 Hydrogen control circuit diagram and signal deception or reduction of the signal for use in engines.

To reduce oil injection, the timing for lifting the fuel injector is adjusted for a shorter duration, with hydrogen gas

injection as a replacement, as illustrated in Fig.6

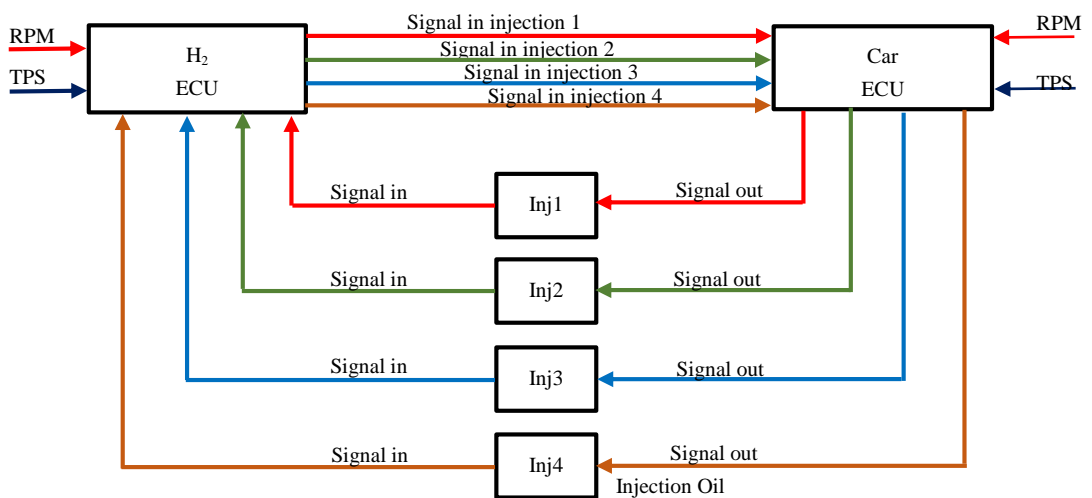


Fig.6 Diagram of using the ECU to control hydrogen gas production and fuel injection.

By adjusting the fuel injector's pressure and resetting it to a negative value, the nozzle pressure will increase. This negative numerical division is determined by referencing the values in the table, where the FRP in value represents the actual value of the car, and the FRP out value is the value

obtained from the adjustment. Through adjustment, by making the out value less than the in value by 10-20%, the pressure in the injector rail increases, resulting in a finer spray of fuel. This improved atomization enhances the mixing of fuel with hydrogen gas, as illustrated in Fig.7

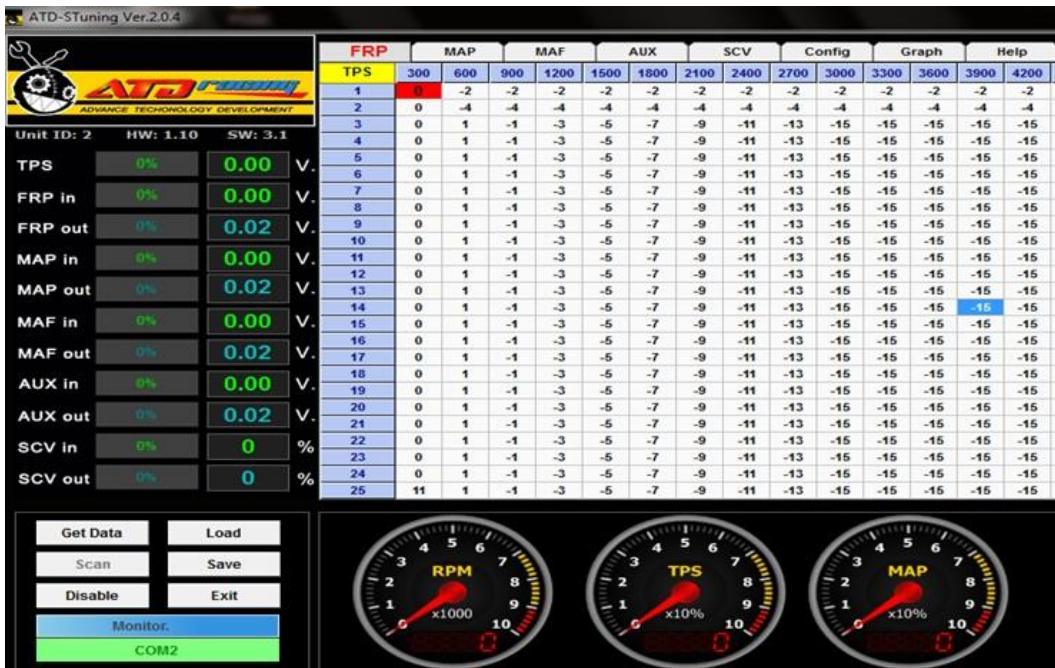


Fig.7 Adjusting the pressure of the fuel injector

Hydrogen gas, obtained through water separation, is channeled into the water storage tank and then directed to the backfire prevention system. Fig.8 illustrates the engine's intake pipe for introducing hydrogen gas into the combustion chamber before suction. The water tank stores water and replenishes the gas separator body with water to maintain system circulation.

The operational component of the gas separator collaborates with an electrical control unit (a microcontroller), which instructs the machine to either separate hydrogen gas from water or cease operations, while overseeing the system's functioning. Additionally, it regulates the separation of hydrogen gas from water to adapt to changes in engine speed.

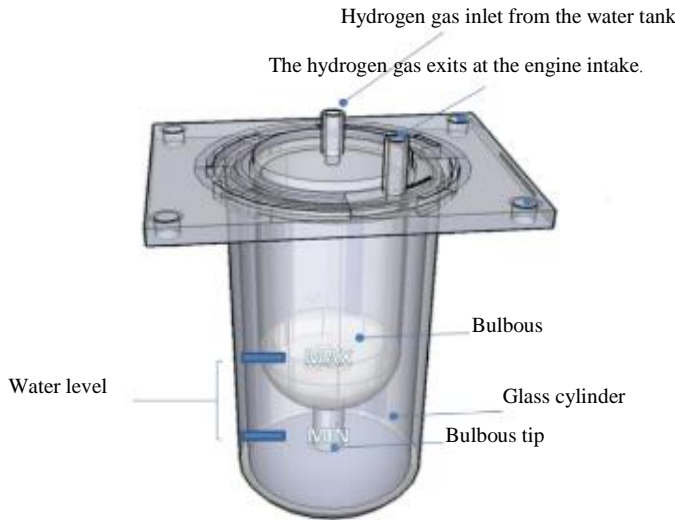


Fig. 8 Backfire arrester

5. Result and Discussion

The research was done by conducting initial tests on an unloaded 2,500 cc engine involved the design of a device for hydrogen gas separation from water, the development of a system for

supplying hydrogen gas to the engine, and subsequent testing of the engine. Fig.4-7 display the results of experiments conducted at constant engine speeds of 1,100, 1,300, 1,500, and 1,700 revolutions per minute (RPM)

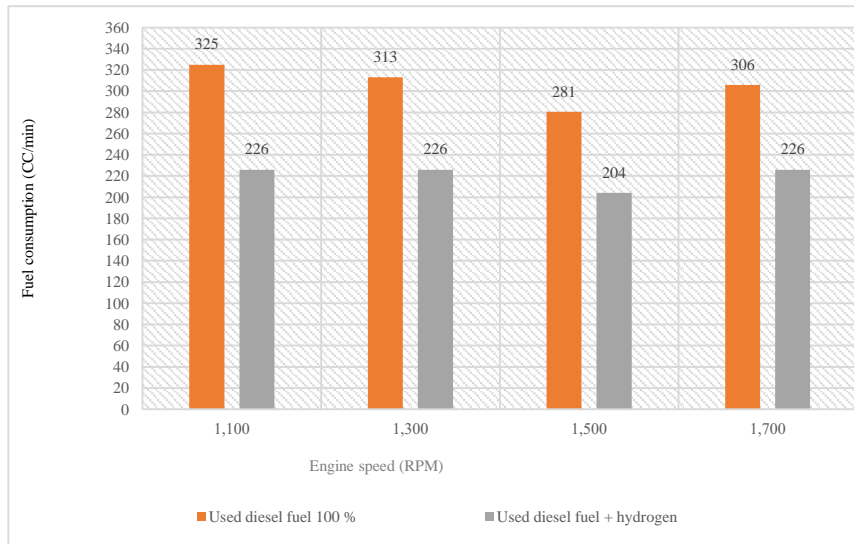


Fig. 9 Comparison of fuel consumption rates between using only diesel fuel and using diesel fuel combined with H₂.

Fig. 9 shows the comparison of fuel consumption rates between using only diesel fuel and using diesel fuel combined with H₂. The data was collected 5 times, for 15 minutes each time, at different speeds.

At constant engine speeds with varying RPMs of 1,100, 1,300, 1,500, and 1,700 revealed that, at 1,500 RPM, the fuel consumption rate was the lowest. When using only diesel fuel, the average consumption rate was 281 CC/min, and with the combination of diesel fuel and H₂, the average consumption rate decreased to 204 CC/min, resulting in a fuel savings of 77 CC/min. The highest fuel consumption rate occurred at 1,100 RPM. The average consumption rate using only diesel fuel was 325 CC/min, while combining diesel fuel

with H₂ resulted in an average consumption rate of 226 CC/min, leading to a fuel savings of 99 CC/min. At 1,300 RPM, there was a fuel savings of 87 CC/min, and at 1,700 RPM, the fuel savings amounted to 80 CC/min.

Electrolysis was employed to separate hydrogen gas from water for blending with engine fuel. This process utilized direct current electricity with a voltage ranging from 12 to 14.5 volts and an electric current between 10 and 13 amps to produce hydrogen gas, which was then mixed with the fuel. As illustrated in Fig. 10, tests were conducted at constant engine speeds of 1,100, 1,300, 1,500, and 1,700 RPM.

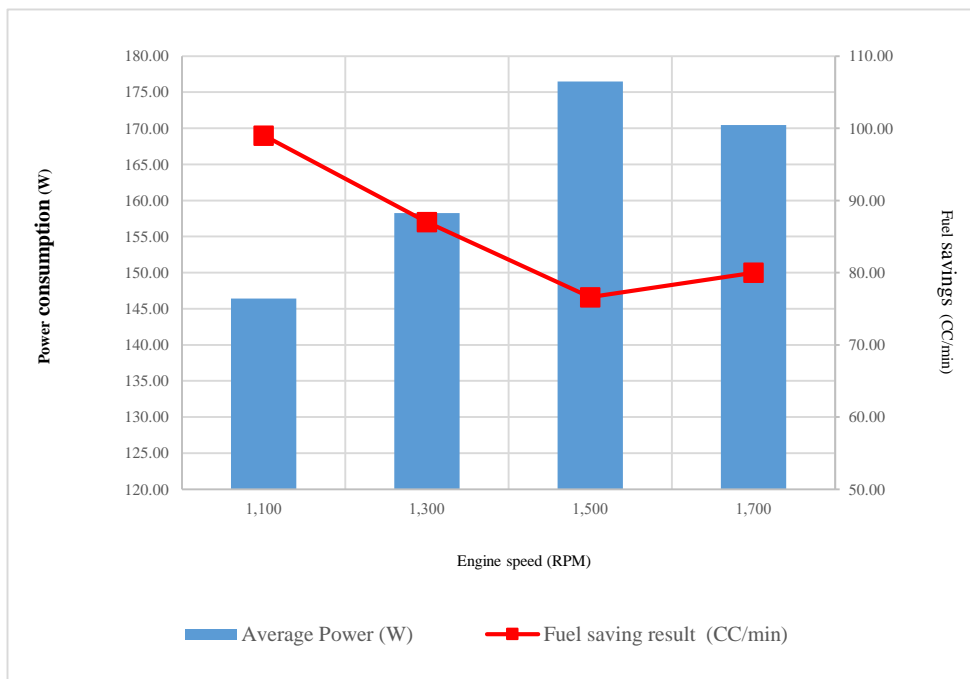


Fig. 10 Means of power consumption compared to fuel savings

As shown in Fig.10, the electricity used to separate hydrogen gas from the water was derived from car batteries that had been charged by the engine's alternator. In this test, a DC voltage of 12 volts, a maximum current of 14 A, and an average power of 163 W were utilized. At 1,100 RPM, the engine consumed the least amount of power, 146.41 W, according to this test, resulting in a 99.00 CC/min fuel savings, or 68 CC/ min/ W when

demonstrated as a ratio of fuel savings to power consumption. As for the engine speed at 1,500 RPM, it consumed the most power, 176.46 W, resulting in fuel savings of 76.60 CC/min or accounting for a ratio of fuel savings to the power consumption of 43 CC/min/W, whereas the engine speeds at 1,300 and 1,700 RPM accounted for ratios of fuel savings to the power consumption of 55 and 47 CC/min/W, respectively.

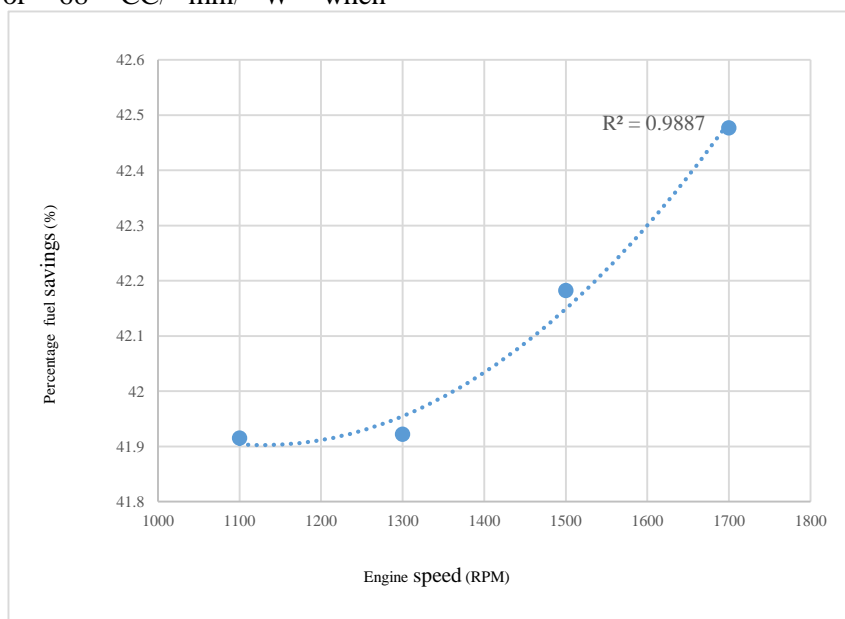


Fig. 11 Percentage of fuel savings from consumption of H₂ fuel obtained from water separation (%)

Fig. 11 shows the results of tests conducted at various engine speeds, based on the percentage of fuel savings achieved by using H₂ fuel separated from water and mixed with diesel fuel. It can be seen that the percentage of fuel savings tends to increase at higher engine speeds, with a trend line modeled as a polynomial with an R² value of 0.9887.

Engines that use fuel mixed with hydrogen gas produce a certain amount of pollution. This pollution is measured by assessing the levels of black smoke, PM10, and PM2.5 from combustion. A comparison is then made between the emissions using 100% fuel and those with hydrogen is mixed with the fuel according to various engine speeds, as shown in Fig.7.

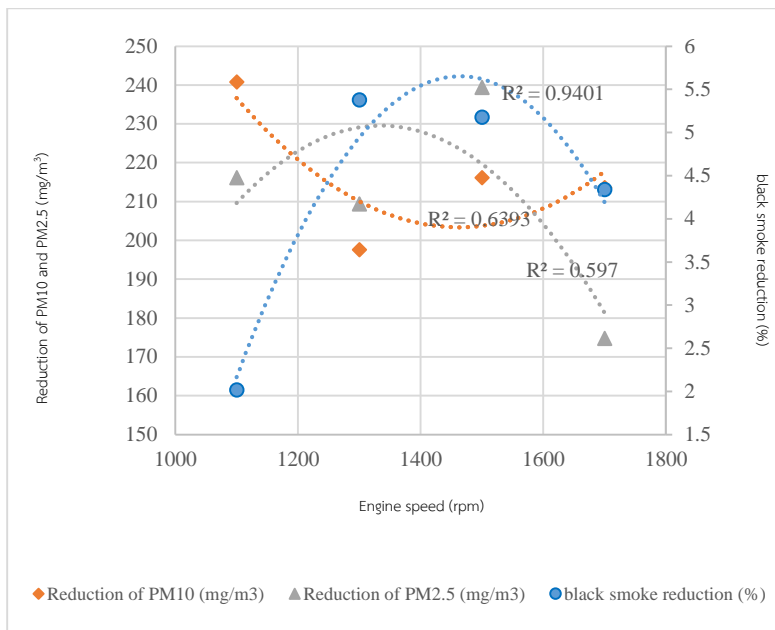


Fig. 12 Comparison of reduction of black smoke (%) with PM 10 and PM 2.5 at different engine speeds

Fig. 12 is a comparison of the reduction of black smoke (%) with PM 10 and PM 2.5 at different engine speeds. found that the trend toward reducing the amount of black smoke At 1,400–1,500 rpm, black smoke is released more than at other rpms. The amount of fuel must be tested again. PM 10 emissions will be less at 1,400–1,500 rpm and PM.2.5 when the engine speed increases. comes in smaller quantities.

5. Conclusions

In conclusion, the primary goal of this research was to extract hydrogen gas from water, aiming to utilize it as fuel for internal combustion engines as a cleaner alternative to conventional fossil fuels. An additional objective was to address prevalent air pollution resulting from

incomplete combustion in existing diesel engines. Experimental tests were conducted on both a 2,500-cc engine and an unloaded engine, spanning constant speeds of 1,100, 1,300, 1,500, and 1,700 RPM.

Analyzing the test results revealed that the highest fuel consumption occurred at 1,100 RPM. Specifically, while the average consumption rate for diesel fuel alone was 325 CC/min, the introduction of hydrogen gas reduced it to 226 CC/min, resulting in substantial fuel savings of 99 CC/min. In terms of electrical usage, the highest recorded electric current at 14 A, corresponding to an average power of 163 W, was observed at 1,100 RPM. Notably, this speed also demonstrated the engine's optimal energy efficiency, consuming a

minimal amount of energy at 146.41 watts and preserving the most gasoline at 99 cc/min.

As of September 30, 2022, Thailand had 1,041,920 diesel-powered vehicles, mandated by legislation requiring diesel propulsion [10]. With an average daily consumption of 60 liters per vehicle [3], the nation collectively consumed approximately 62.52 million liters of diesel daily. If the clean energy generated from the hydrogen-water separation process were harnessed as fuel for diesel engines, the potential reduction in daily diesel consumption could reach 26.25 million liters, presenting a significant environmental benefit. Previous studies have suggested that integrating a hydrogen gas separation device with diesel fuel may result in a substantial 40% reduction in gasoline usage.

Abbreviations

°C	<i>Degree Celsius</i>
CH ₄	Methane
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
H ₂	Hydrogen
H ₂ S	Hydrogen Sulfide
N ₂	Nitrogen
η _g	Synthetic Gas
O ₂	Oxygen
RPM	Revolutions per minute
cc	Cubic Centimeters
CC/min	Cubic Centimeters Per minim
W	Watt
LPG	Liquefied Petroleum Gas
NGV	Natural Gas for Vehicles

CNG	Compressed Natural Gas
PM10	Dust particles in the air have a diameter of 10 microns.
PM2.5	Dust particles in the air have a diameter of 2.5 microns.

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