GLOBAL SUMMIT ON SUSTAINABLE INNOVATION, AND GREEN TECHNOLOGIES (GS-SIGRET) PROCEEDINGS, Vol.1, 2025, pp. 39-46

Investigation of Hydrogen as Dual Fuel on Diesel Engine Performance

Submitted 25 September 2024, Revised 15 December 2024, Accepted 31 December 2024

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Abstract

One of the gas fuels created to enhance the diesel engines' ability to burn fuel efficiently is hydrogen. An improvement known as dual fuel technology makes use of two fuels in order to maximize combustion inside the combustion chamber. Hydrogen gas was added to diesel fuel and mixed through the diesel engine's intake manifold for this study. The purpose of the testing is to determine the comparison of power, torque, specific fuel consumption, and thermal efficiency between the use of dexlite fuel and dual fuel dexlite/hydrogen with variations in hydrogen flow rates of 2, 4, and 6 liters per minute (lpm) introduced into the combustion chamber of a single-cylinder diesel engine. The variances are at engine speeds of 1200, 1400, 1600, 1800, and 2000 rpm. The research results indicate that hydrogen dual fuel affects the power and torque performance of diesel engines. The influence of hydrogen dual fuel can enhance diesel engine performance, resulting in an increase in power of 0.154 kW and torque of 0.739 Nm compared to the absence of hydrogen addition. The highest power and torque are achieved at a hydrogen flow rate of 6 lpm at an engine speed of 2000 rpm, which are 1.65 kW and 7.85 Nm, respectively. The addition of hydrogen as a supplementary fuel in diesel engines helps to optimize the combustion process. The high calorific value of hydrogen can release greater energy based on the mass of what is burned during combustion. Dual fuel has a significant impact on specific fuel consumption (sfc) and thermal efficiency due to the presence of a hydrogen fuel mixture, which has a very small mass and a higher calorific value compared to dexlite. A significant increase in specific fuel consumption (sfc) occurs at hydrogen flow rates of 4 lpm and 6 lpm. This is due to the flammable nature of hydrogen, which allows for complete combustion to take place within the combustion chamber. The best sfc and thermal efficiency values are found at a flow rate of 6 lpm with the engine running at 2000 rpm, which are 0.324 kg/kWh and 21.56%, respectively. The smaller the sfc value, the greater the thermal efficiency. The high calorific value of hydrogen produces a large amount of energy during the combustion process.

Keywords: Dual Fuel, Diesel Engine, Hydrogen, Engine Performance, Engine Efficiency

INTRODUCTION

The technology of internal combustion engines is increasingly being developed, one of which is the advancement in the use of hydrogen fuel. The use of diesel engines can be claimed to be 25% more economical and efficient compared to gasoline engines (Kalamajaya, 2016). However, the use of diesel fuel, specifically the dexlite type, is still suspected to be a cause of air pollution in urban areas. Dexlite fuel is a type of fuel with a low cetane number, which results in incomplete combustion. Therefore, the innovation of using hydrogen as an environmentally friendly alternative fuel is increasingly becoming the focus of research for innovators. Hydrogen can be used as a breakthrough to help maximize the combustion of fuels that burn imperfectly. Considering that hydrogen is a highly flammable fuel, one alternative technology that can be implemented is the application of a dual fuel system, which involves mixing dexlite fuel with hydrogen. The use of this dual fuel system is expected to enhance the efficiency of internal combustion engines. The increase in the efficiency of internal combustion engines can be achieved through three methods: before combustion technology, combustion process technology, and after combustion technology.

Dual fuel technology is the development of technology using two fuels with the aim of maximizing the combustion process. Increasing efficiency with dual fuel is a technology for enhancing efficiency using a before combustion method. The addition of hydrogen to a single-cylinder diesel engine using turbocharging demonstrates better performance compared to without the addition of hydrogen (Yilmaz & Gumus, 2018). The application of dual fuel technology in diesel engines involves the addition of hydrogen to the engine's intake manifold. Regulating the flow rate of hydrogen gas mixed with ambient air in the diesel engine's intake manifold can help achieve complete combustion in the combustion reaction within the diesel engine's combustion chamber.

The technology for developing hydrogen fuel is currently being tested by automotive manufacturers to create engines that are highly efficient and environmentally friendly. One of the results of research on the addition of hydrogen fuel is the reduction of CO_2 emissions and a decrease in opacity due to the lower carbon content in the dual fuel system. The application of hydrogen-dexlite dual fuel technology results in improved fuel consumption efficiency, enhances thermal efficiency, and reduces emissions of CO and HC (Koten, 2018).

METHOD

This research focuses on the effects of adding hydrogen to the intake manifold of a diesel engine on the engine's performance. The study was conducted by analyzing the experimental results and observing the performance of the diesel engine that had hydrogen gas added to the intake manifold. The experiment involved introducing hydrogen gas from a cylinder through a flow meter into the diesel engine's intake manifold. The addition of hydrogen is carried out with several variables, namely by varying the flow rate of hydrogen at 0, 2, 4, and 6 lpm at speeds of 1200, 1400, 1600, 1800, and 2000 rpm. Meanwhile, the independent variables in this study are the flow rate of hydrogen gas and the engine speed. Meanwhile, the dependent variables are power output, torque, specific fuel consumption, and thermal efficiency.

Table 1. Table of Properties of Diesel Engine

Items	Unit
Brand	Dong Feng R175 A
Type of Engine	1 cylinder, 4 stroke
Combustion system	Precombustion chamber
Bore x Stroke	75 x 80 mm
Displacement	0,353 liter
Maximum output	7 HP
Rated speed	2600 rpm
Fuel consumption	≤ 206 gr/hp.hr
Cooling system	Evaporative
Net weight	65 kg

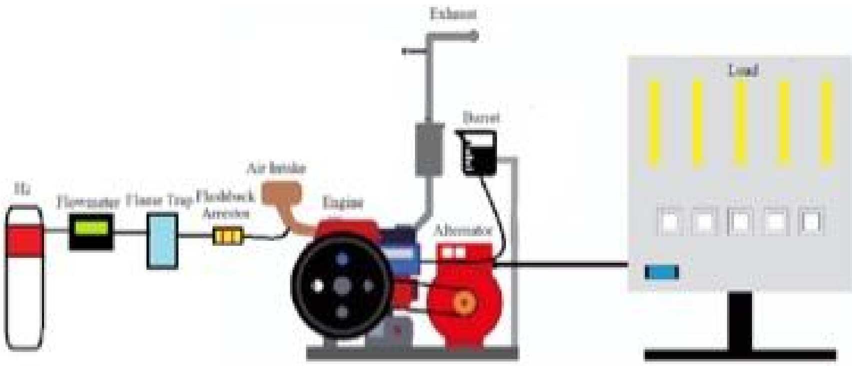

Figure 1. Schematic Diagram of Experiment

To prevent workplace accidents during research, two safety devices are needed: a Flashback Arrestor and a Flame Trap. The principle of the Flashback Arrestor is to open the valve if there is a one-way flow rate and to help prevent gas flow in the event of a pressure shock or to withstand back pressure when the diesel engine is operating. The Flashback Arrestor is placed closest to the Intake Manifold to maximize safety. The working principle of a Flame Trap is to contain the fire so that it does not spread towards the source of the gas flow. In the event of a workplace accident involving burning gas while the flow is continuous, the Flame Trap functions to prevent the fire from spreading back to the gas source. The Flame Trap serves as a secondary safety device and is placed after the flowmeter.

RESULTS AND DISCUSSIONS

Dual fuel testing using hydrogen and dexlite has been conducted in the combustion engine laboratory of the Mechanical Engineering Department at Universitas Sultan Ageng Tirtayasa. Power is the ability or energy used per unit of time. This test uses a light load of 500 watts and 1000 watts. The test results show the power transmitted to turn on the lamp as shown in the table below.

Table 2. Result of Power Engine

Power (kW)				
rpm	0 lpm	2 lpm	4 lpm	6 lpm
1200	0,361	0,397	0,410	0,454
1400	0,492	0,518	0,548	0,593
1600	0,870	0,900	0,950	0,981
1800	1,163	1,203	1,260	1,313
2000	1,497	1,545	1,576	1,651

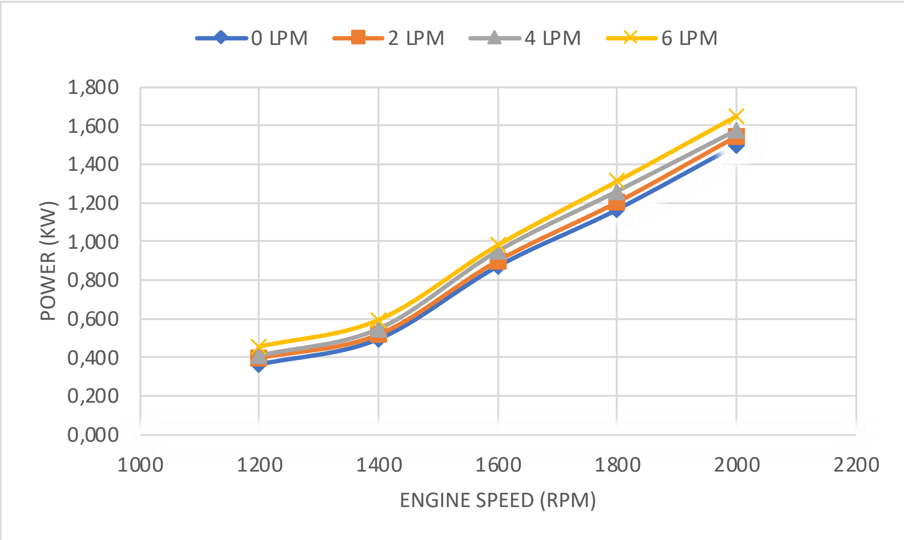

Figure 2. Graphic of Power Engine

The increase in power is directly proportional to the increase in engine speed. The largest increase occurs with a hydrogen mixture at 6 lpm and an engine speed of 2000 rpm, amounting to 0.154 kW. The density of the fuel affects engine calibration and power because the fuel density influences combustion time and exhaust gas emissions. The addition of dual fuel can increase the power of the diesel engine compared to the absence of hydrogen addition. The calorific value of hydrogen is higher than that of dexlite; a higher calorific value can release greater energy based on the mass of what is burned during combustion (Layton, 2008)

Torque or Moment of Force is the ability of an object to perform rotational motion. The results of the testing of hydrogen fuel and the dexlite mixture can be seen in the table below.

Table 3. Result of Torque Engine

Torque (Nm)				
rpm	0 lpm	2 lpm	4 lpm	6 lpm
1200	2,773	3,122	3,261	3,559
1400	3,288	3,503	3,677	3,997
1600	5,144	5,343	5,586	5,813
1800	6,133	6,388	6,601	6,867
2000	7,110	7,255	7,464	7,849

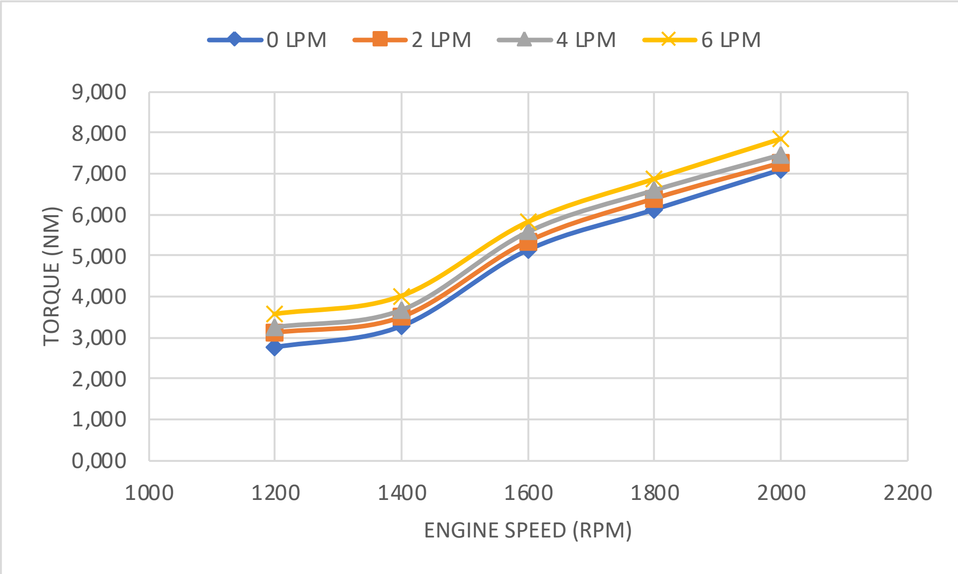

Figure 3. Graphic of Torque Engine

When the machine performs its work steps, there is a downward vertical force that causes the crankshaft to rotate. The torque from the crankshaft is used to drive the gears and pulleys. Similarly to power, the increase in engine speed is directly proportional to the increase in torque. The addition of hydrogen at a rate of 6 liters per minute at an engine speed of 2000 rpm can increase torque by 0.739 Nm. The addition of hydrogen can enhance power and torque performance in diesel engines.

Specific Fuel Consumption is defined as the ratio of the mass flow rate of fuel to the power produced by the engine. When burning two different fuels, the calculation involves determining the mass flow rate for each fuel, namely the mass flow rate of dexlite fuel and hydrogen gas fuel.

Table 4. Result of Fuel Consumption of Engine

SFC (kg/kWh)				
rpm	0 lpm	2 lpm	4 lpm	6 lpm
1200	1,863	1,562	0,706	0,488
1400	1,638	1,475	0,690	0,478
1600	1,098	0,933	0,495	0,365
1800	1,010	0,871	0,477	0,343
2000	0,926	0,830	0,452	0,324

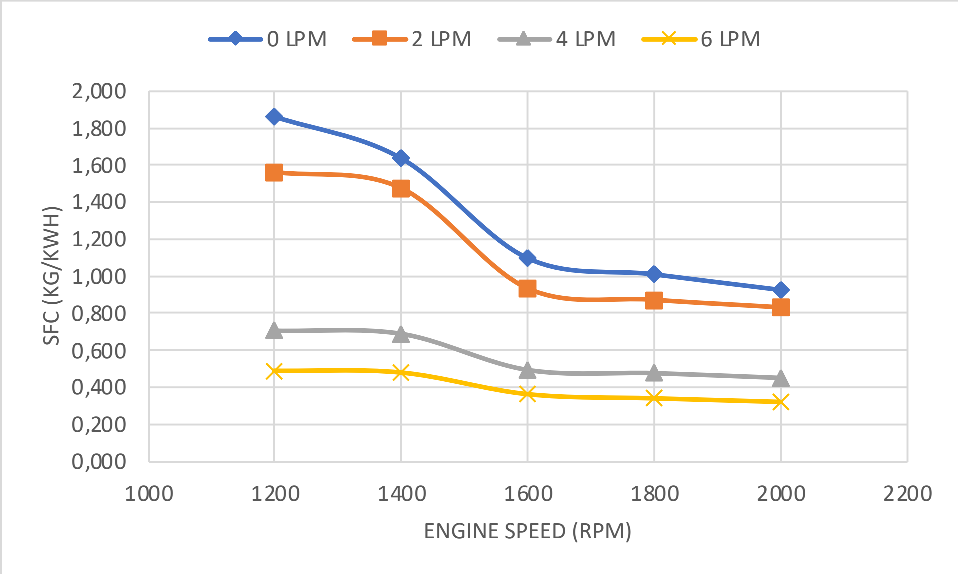

Figure 4. Graphic of Specific Fuel Consumption (SFC)

Due to hydrogen's very low mass, hydrogen fuel has a small mass flow rate; the smaller the SFC value, the more fuel-efficient and environmentally friendly the fuel is. At flow rates of 4 lpm and 6 lpm, hydrogen fuel can burn optimally and produce a very good SFC value compared to a hydrogen flow rate of 2 lpm. The addition of dual fuel helps achieve more optimal combustion in diesel engines.

Thermal efficiency is the ratio of the heat used in the work process to the power generated for rotating the crankshaft in a machine, compared to the heat that is wasted.

Table 5. Result of Efficiency Thermal of Engine

Efficiency Thermal (%)				
rpm	0 lpm	2 lpm	4 lpm	6 lpm
1200	4,13	4,80	9,76	12,85
1400	4,70	5,11	10,24	13,66
1600	7,01	8,09	14,51	18,48
1800	7,62	8,70	15,27	20,17
2000	8,31	9,15	16,26	21,68

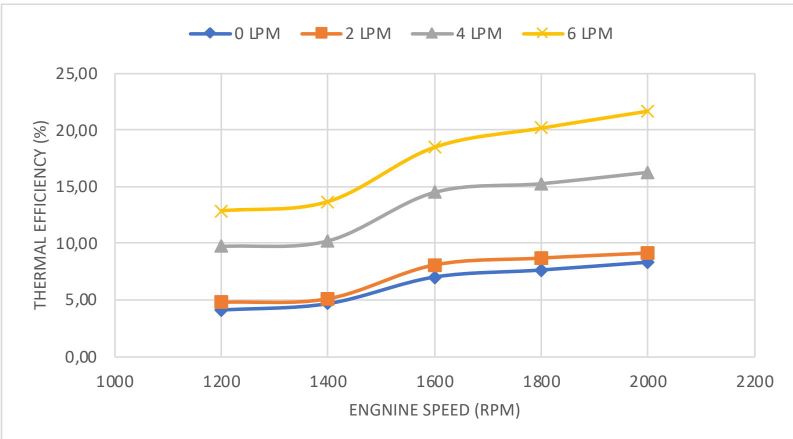

Figure 5. Graphic of Thermal Efficiency

The higher the thermal efficiency, the more efficiently the machine operates because more energy is used for conversion into power. Thermal efficiency is inversely proportional to the SFC value; if the SFC decreases, the thermal efficiency will increase. Due to the small mass of hydrogen, the more hydrogen is drawn into the combustion chamber and burns completely, the greater its thermal efficiency. The properties of hydrogen, having a high calorific value, can enhance the performance and combustion characteristics of diesel engines (Hosseini *et al*., 2023).

CONCLUSIONS

The testing of hydrogen fuel and its mixture with dexlite has been conducted. From the experiment, several conclusions can be drawn:

1. Dual fuel affects the power and torque performance of the diesel engine. The influence of dual fuel can enhance the performance of the diesel engine in terms of power and torque by 0.154 kW and 0.739 Nm compared to without the addition of hydrogen. The highest power and torque were achieved at a hydrogen flow rate of 6 lpm at 2000 rpm, amounting to 1.651 kW and 7.85 Nm. The addition of Dual Fuel helps to optimize engine combustion. The high calorific value of hydrogen can release greater energy based on the mass of what is burned during combustion. Power and torque from the engine are influenced by the calorific value of the fuel.
2. Dual fuel significantly affects the specific fuel consumption (SFC) and thermal efficiency due to the presence of a hydrogen fuel mixture, which has a very small mass and a higher calorific value compared to dexlite. To calculate the SFC value and thermal efficiency using mass flow rates, there is a rapid increase. A significant rise occurs at hydrogen flow rates of 4 lpm and 6 lpm because, at these two flow rates, hydrogen can operate optimally compared to 0 lpm and 2 lpm. The best SFC value and thermal efficiency are at a flow rate of 6 lpm and engine speed of 2000 rpm, with an SFC of 0.324 kg/kWh and thermal efficiency of 21.68%. The smaller the SFC value, the greater the thermal efficiency, and these results indicate that the engine is operating optimally.

ACKNOWLEDGEMENT

The authors would like to acknowledge the University of Sultan Ageng Tirtayasa for providing funding to carry out the research project by Research Grant (PTI) 2024.

REFERENCES

Ghosh, B. (2024). Chapter 6.1 - Potential of hydrogen in powering mobility and grid sectors. In D. Jaiswal-Nagar, V. Dixit, & S. Devasahayam (Eds.), *Towards Hydrogen Infrastructure* (pp. 349–376). Elsevier.

Hosseini, S. H., Tsolakis, A., Alagumalai, A., Mahian, O., Lam, S. S., Pan, J., Peng, W., Tabatabaei, M., & Aghbashlo, M. (2023). Use of hydrogen in dual-fuel diesel engines. *Progress in Energy and Combustion Science*, *98*, 101100.

Kalamajaya, M. F. (2016). Perbedaan Konsumsi Bahan Bakar dan Kepekatan Gas Buang Mesin Diesel Menggunakan Bahan Bakar Solar dan Campuran Solar dengan Minyak Cengkeh. *Universitas Negeri Semarang*.

Koten, H. (2018). Hydrogen effects on the diesel engine performance and emissions. *International Journal of Hydrogen Energy*, *43*.

Layton, B. (2008). A Comparison of Energy Densities of Prevalent Energy Sources in Units of Joules Per Cubic Meter. *International Journal of Green Energy*, *5*, 438–455.

Maymuchar, & Wibowo, C. S. (2011). Pengaruh Mutu Bahan Bakar Minyak Solar 48 dan 51 terhadap Pembentukan Emisi Partikulat pada Kendaraan Bermotor. *Jurnal Lemigas*, *45*(3).

Miyamoto, T., Hasegawa, H., Mikami, M., Kojima, N., Kabashima, H., & Urata, Y. (2011). Effect of hydrogen addition to intake gas on combustion and exhaust emission characteristics of a diesel engine. *International Journal of Hydrogen Energy*, *36*(20), 13138–13149.

Monasari, Firdaus, A., & Qosim, N. (2021). Pengaruh Penambahan Zat Aditif Pada Campuran Bahan Bakar Bensin – Bioethanol Terhadap Specific Fuel Consumption. *Jurnal Pendidikan Teknik Mesin Undiksha*, *9*, 1–10.

Tsujimura, T., & Suzuki, Y. (2017). The utilization of hydrogen in hydrogen diesel dual fuel engine. *International Journal of Hydrogen Energy*, *42*.

Winangun, K., Setiyawan, A., Sudarmanta, B., Buntoro, G. A., Pangestu, R. E., Nurgito, A., & Prasetyo, T. (2023). *Penggunaan bahan bakar terbarukan (biodiesel-hidrogen) pada mesin diesel dual fuel untuk mendukung energy transition di Indonesia*.

Yadav, V. S., Soni, S. L., & Sharma, D. (2014). Engine performance of optimized hydrogen-fueled direct injection engine. *Energy*, *65*, 116–122.

Yilmaz, I. T., & Gumus, M. (2018). Effects of hydrogen addition to the intake air on performance and emissions of common rail diesel engine. *Energy*, *142*, 1104–1113.