BIS ENERGY AND ENGINEERING

Volume 1 2024 | DOI: 10.31603/biseeng.75
5th Borobudur International Symposium on Science and Technology (BIS-STE) 2023

UNIMMA PRESS
UNIVERSITAS MUHAMMADIYAH MAGELANG

The impact of adding hydrogen on the performance of a CI engine fueled by palm biodiesel

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Abstract

Compression ignition engines are utilized extensively in the support of human life, such as in agriculture and transportation. Diverse factors, such as dwindling oil sources and the environmental impact of diesel fuel as a compression engine fuel, necessitate those researchers seek alternate fuels to lessen reliance on fossil oil. Palm oil biodiesel is the alternative fuel to diesel fuel, which is widely utilized in Indonesia. In addition, hydrogen gas can be used in compression engines as a supplement to fossil fuels. In this study, the effect of hydrogen enrichment on palm biodiesel (B100) combustion in compression ignition engines was investigated. The research was conducted on a single-cylinder diesel engine with constant speed and load. The purpose of this investigation was to evaluate the performance and exhaust emissions of dual-fuel diesel engines. At 50% medium load, the findings of this investigation indicate an improvement in thermal and power efficiency of 65% and 0.8%, respectively, as well as an 82% reduction in fuel consumption compared to biodiesel fuel. The addition of hydrogen gas has a good effect on lowering smoke and NO emissions, while boosting EGT emissions.

Keywords

Hydrogen, Fuel, Palm biodiesel

Introduction

The demand for energy is a key issue in every region of the globe. In many nations, fossil fuels continue to provide the majority of the energy used to sustain human life. Four sectors, including the industrial, transportation, residential, and commercial sectors, are users of energy. Transportation is the second largest consumer of energy for human needs [1][2][3]. Compression ignition-powered cars dominate the transportation industry due to their user-friendliness and superior fuel economy in comparison to other vehicles. The majority of transportation energy originates from fossil-based petroleum products such as gasoline, diesel, and kerosene. However, fossil energy reserves are dwindling each year, which has prompted the government and scientists to consider alternatives to fossil fuels. Among the alternatives proposed by the researchers is the

Published:
October 20, 2024

Selection and Peer-review under the responsibility of the 5th BIS-STE 2023 Committee

development of renewable energy sources such as geothermal, solar, wind, and waves, among others. Nonetheless, this method necessitates expensive equipment and can strain the state's finances. Therefore, academics are searching for community-applicable alternatives that are renewable, sustainable, and economically valuable [4][5][6]. Recently, many researchers are interested in clean, renewable and sustainable hydrogen energy under certain conditions [7][8][9]. The use of hydrogen cannot be directly used in diesel engines, it must be pilot fuel as the ignition of the combustion process in the combustion chamber.

Biodiesel for diesel engines is another solution proposed by many researchers to the problem of dependence on the use of fuel oil [10–12]. Biodiesel is a renewable energy source derived from waste oil, animal fats, and the preponderance of vegetable oils through transesterification processes. Renewable and sustainable resources are biodiesel's primary advantage over conventional fuels. It is also recognized that burning biodiesel is superior since it emits less carbon monoxide into the environment. On the other hand, the use of biodiesel has a number of disadvantages, including the issue of crude oil supply consistency, higher fuel consumption due to reduced heating value, improper viscosity value, poor cold operating qualities, and nitrogen oxide emission value (NOx). since it is more height [13–15]. However, bio-diesel remains the best alternative to diesel engines. Biodiesel can be incorporated with diesel or used alone in diesel engines without the need for engine modifications [16-17].

The operation of a dual-fuel engine by injecting gas fuel and air ignited by biodiesel as pilot or ignition fuel into the intake manifold [14-17]. Hydrogen is one of the future fuels in the automotive industry because it is a pure, renewable fuel that can be sourced from nature [18]. Utilization of hydrogen gas into compressed engines as additional fuel or primary fuel and diesel fuel as pilot fuel. Hydrogen fuel has an auto-ignition temperature of 585 degrees Celsius, allowing its use in high-compression engines like diesel engines [19].

Several researchers have conducted research on the use of hydrogen in diesel engines, among others [20] Research was undertaken by introducing hydrogen and hydroxy gases to microalgae-based biodiesel. With the usage of microalgal biodiesel, engine power and torque have dropped (without hydrogen). The introduction of hydrogen and hydroxy gases compensates for reduced torque and power output as well as increased carbon dioxide emissions. Next to [21-22] Experiments done on a 4-cylinder diesel engine with varying hydrogen and HHO flow rates at varied loads revealed that 36 LPM of hydrogen and HHO gas provided the maximum energy substitution of 86% and 76%, respectively. At high torque, HC emissions decrease, however NOx emissions increase with the addition of hydrogen and HHO as the temperature falls. CO_2 and smoke are reduced as a result of a drop in carbon content. Increases in combustion duration and decreases in BTE were seen for all mixes except HHO 6 LPM gas. With the addition of hydrogen gas and HHO, the maximum (HRR) occurs near to TDC due to the quicker combustion relative to diesel operation. The dual fuel system provides the benefits of reducing diesel fuel consumption, boosting the thermal efficiency of the engine, and lowering CO and THC exhaust emissions [23-24].

Biodiesel derived from palm oil, which is prevalent in Indonesia, may be inferred to be an environmentally friendly alternative fuel for diesel engines. However, the usage of 100 percent biodiesel impairs engine performance. Diesel engines can be improved by adding small quantities of hydrogen gas. This hydrogen gas has combustible properties and can be used as a diesel engine auxiliary fuel. It is anticipated that the higher thermal value of hydrogen gas compared to biodiesel will improve diesel engine performance. Therefore, diesel engines require the Diesel Dual Fuel (DDF) technology to utilize these two types of fuel.

Method

This study employs the experimental technique, which involves gathering data directly from the output of the equipment. The results of the experiment include the performance and exhaust emissions of dual-fuel diesel engines that run on palm oil biodiesel and hydrogen gas. Wilmar Nabati Indonesia Persero manufactures biodiesel Crude Palm Oil (CPO), whilst Samator Persero produces hydrogen gas. The test was conducted on a diesel dual-fuel (DDF) engine converted from a single-cylinder diesel engine. Experiments began with the conversion of a single-fuel diesel engine to a dual-fuel system. The ECU controls the process for infusing hydrogen gas (H_2) along with intake air through the intake manifold, while biodiesel fuel is pumped directly into the combustion chamber. Flow of hydrogen gas is monitored with a flow meter, while biodiesel fuel is measured with a measuring cup. Using an electric generator with a light load to evaluate engine performance. The test was conducted at a constant load and engine rpm. The fuel utilized is Biodiesel and the flow of hydrogen gas varies between 2.5 and 10 lpm. Thermal efficiency, horsepower, and fuel consumption are analyzed during engine performance testing. Emissions testing of engine exhaust, including EGT, smoke, and NO. The dual fuel diesel engine testing program is illustrated in Figure 1.

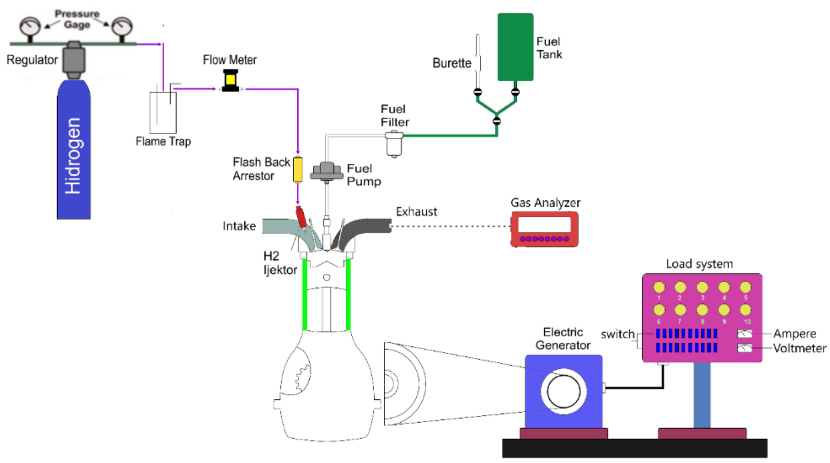

Figure 1. Test equipment schematic

The testing machine is a 4-stroke, direct injection, single-cylinder, water-cooled Diamond DI 800. Specific engine characteristics are listed in Table 1. Table 2 displays the characteristics of palm oil biodiesel fuel and hydrogen gas.

Table 1. Engine Specification

Description	Specification
Model	DI 800 H
Type	One cylinder, four-stroke
Combustion system	Direct injection
Bore x stroke	82 x 78 mm
Displacement	411 cc
Maximum power	7 HP (5.22 kW)/2200 rpm
Continuous power	6 HP (4.47 kW)/2000 rpm
Compression Ratio	18:1
Pilot injection timing	13^o BTDC
Cooling system	Hopper
Fuel injection pressure	220 Kg/cm^2

Table 2. Engine specification

No	Properties	CPO Biodiesel	Hydrogen
1	Density at 15°C (Kg/m^3)	875	0.085
2	Kinematic Viscosity 40°C (mm^2/s (cSt))	4.5	0
3	Cetane Number (Min)	58	5-10
4	Flash Point (°C, Min)	140	
5	Fog Point (°C, Max)	15.4	
6	Lower Heat Value (kJ/kg)	39.910	119.810
7	Auto Ignition Temperature (°C)	>101	585
8	Stoichiometric Air-Fuel Ratio	12.5	34.3

Results and Discussion

Based on test results, this paper will investigate the effect of adding hydrogen gas to a dual-fuel diesel engine (DDF) with biodiesel fuel from palm oil at medium load (50%). The presentation and analysis of data is divided into two categories: engine performance, which includes power, thermal efficiency, and specific fuel consumption; and engine specifications. The second piece of information is exhaust emissions, which include CO, HC, NO, EGT, and smoke.

Engine performance

Figure 2 depicts, with black lines, the relationship between power and hydrogen gas flow at constant loadIn the experiment, the use of B100 petroleum produced 3.78 kW of output power. The inclusion of hydrogen gas to the B100 increased engine output. The engine generates more power as the flux of hydrogen gas increases. Compared to biodiesel as a single fuel, the flow rate of hydrogen at 7.5lpm increases power by 0.8%. Reasons Higher heating value, faster hydrogen ignition speed, and improved combustion with hydrogen and oxygen molecules can boost engine power [25-26]. However, at a maximum hydrogen flow rate of 10 lpm, engine knocking caused a drop in power. Each of the B100, BH2.5, BH5, BH7.5, and BH10 fuels received a power boost of 3.78kW, 3.73kW, 3.50kW, 3.78kW, and 3.71kW, respectively.

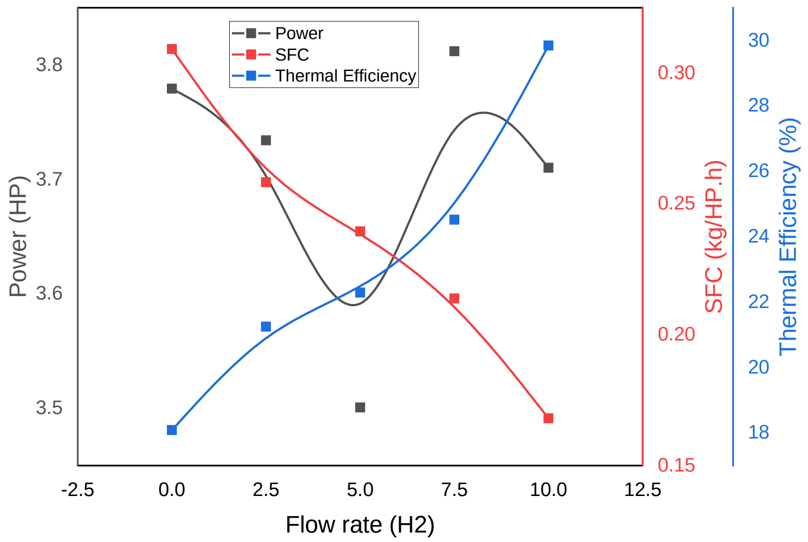

Figure 2. Power, SFC, and BTE various flow rates of hydrogen

In Figure 2, the blue line depicts the thermal efficiency of the brake against the passage of hydrogen gas. The use of hydrogen gas increases the thermal efficiency of dual-fuel diesel engines that use biodiesel as the pilot or ignite fuel. Because hydrogen is combustible, its presence in greater quantities accelerates combustion, which can result in greater thermal efficiency. At a maximum hydrogen flow rate of 10lpm, the increase in BTE was a considerable 65%. The method of introducing hydrogen gas through the intake manifold may result in fuel loss without combustion in the combustion chamber, but it also reduces volumetric efficiency because some of the air is replaced with hydrogen gas [27]. This increase is due to the faster-than-desired combustion process, which reduces the time required to generate power and release heat [28]. Thermal efficiency increases of 18.09%, 21.25 %, 22.29%, 24.52%, and 29.85 % for Biodiesel (B100), BH2.5, BH5, BH7.5, and BH10, respectively.

The SFC graph is inversely proportional to power and thermal efficiency. Figure 2 red line indicates that as the flow of hydrogen increases, the SFC for both single- and dual-fuel engines decreases. The highest reduction in 10lpm hydrogen flow is 82.35 percent when compared to biodiesel with a single fuel. This decrease is the result of an increase in cylinder temperature, which promotes the combustion of injected fuel and the production of power. Therefore, less fuel is needed to produce the same quantity of energy. This is further supported by [24].

Exhaust gas emissions

Exhaust gas temperature (EGT) findings for biodiesel single feedstock and dual fuel with varying hydrogen flow rates of 2.5lpm, 5lpm, 7.5lpm, and 10lpm are depicted in Figure 3 with a black line. A K-type thermocouple with a digital display is utilized to determine the temperature of exhaust gas. When hydrogen gas is not provided to the engine, it is known that the usage of CPO biodiesel results in an exhaust gas temperature of around 234°C. At a flow rate of 10lpm hydrogen, the inclusion of hydrogen gas increases the exhaust gas temperature by a maximum of 40.59 percent compared to biodiesel alone.

The increase in exhaust gas temperature is attributable to the threefold greater thermal value of hydrogen gas in comparison to biodiesel [29-30]. The rise in EGT for each hydrogen stream was 234°C for B100, 256°C for BH2.5, 260°C for BH10, 307°C for BH5 and 329°C for BH10.

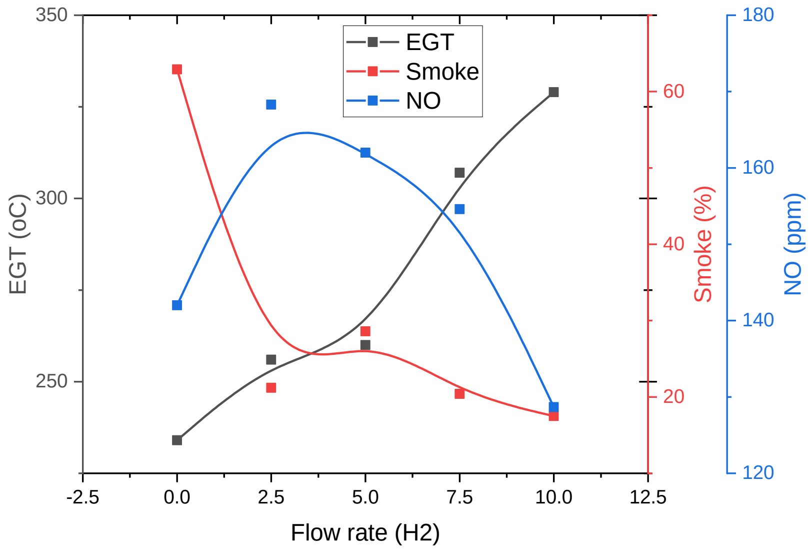

Figure 3. Emissions of smoke, NO, and EGT on hydrogen flow rate

Poor combustion, lower oxygen demand, an imbalanced air-to-fuel combination, and a low combustion chamber temperature contribute to the incidence of smoke emissions [31]. Figure 3 depicts, with a red line, the fluctuation in smoke production caused by the addition of hydrogen during the test. Smoke emissions in diesel engines powered with palm oil biodiesel at 50% load decrease with increased hydrogen flow. This is because the presence of hydrogen raises the temperature of the combustion chamber, making it more suitable for burning biodiesel fuel and promoting a more thorough combustion [32]. A considerable drop was seen between biodiesel fuel and 10lpm hydrogen flow, from 62.90% in biodiesel to 17.50% in 10lpm hydrogen.

NO emissions of 142 ppm at maximum production can be achieved by using pure palm biodiesel, as depicted by the blue line in Figure 3. There is an increase in NO emissions during dual fuel running with hydrogen injection. An increase of 18.3% in NO emissions from 142 to 168 parts per million. When hydrogen is induced, the combustion rate, cylinder pressure, and combustion chamber temperature all increase, causing a rise in NO emissions. Hydrogen has a faster ignition rate and higher heating value than diesel, which increases the likelihood of complete combustion. This increases the cylinder's peak pressure, which in turn increases the temperature within the cylinder [33]. However, the increased amount of hydrogen decreases NO emissions; this may be due to the more efficient combustion factor.

Conclusion

The effect of introducing hydrogen gas into a dual-fuel diesel engine fueled by palm oil biodiesel has been determined in this experiment. Work conducted on the performance and exhaust emissions of a single-cylinder diesel engine operating at 50 percent of its utmost 5kW load continuously. By adding hydrogen gas to a single-cylinder diesel engine powered primarily by palm biodiesel, engine performance under moderate loads can be enhanced. With signs of improved power and thermal efficiency, as well as reduced fuel consumption. The addition of hydrogen gas to biodiesel fuel also has a positive impact on exhaust emissions. all exhaust emissions decreased, except for a slightly increased EGT.

Acknowledgement

Contract number 1687.206/PD/I.3/D/2022 was supplied by the Research and Development Council for Higher Education at the Central Leadership of Muhammadiyah, which is being thanked by the first author.

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