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Article

Effect of Blower Power and Engine Speed Variations on Engine Component Temperatures Fueled by B40 and Off-Grade CPO

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Abstract

This study examines the effect of blower power variation and engine speed on the temperature of diesel engine components fueled by B40 and off-grade Crude Palm Oil (CPO). The experiment was conducted using a Kubota RD 65 DI-NB diesel engine with a constant electrical load of 4 kW at two engine speeds: 1200 and 2000 RPM. The off-grade CPO was preheated to 100°C, while B40 was used without any special treatment. The blower air supply was varied from 0% to 100% to evaluate its impact on the engine's thermal behavior. The results indicate that increasing blower power up to 100% causes a rise in temperature in the cylinder head, cylinder block, exhaust pipe, and coolant tank, whereas a decrease in temperature is observed in the intake pipe. Under all engine speed conditions, engines fueled with off-grade CPO showed higher average temperatures compared to those using B40, with increases of 4.81% in the cylinder head, 8.47% in the cylinder block, 10.16% in the intake pipe, 6.86% in the exhaust pipe, and 5.81% in the coolant tank. These temperature increases are attributed to the higher oxygen content and viscosity of off-grade CPO, which lead to larger fuel droplets and incomplete combustion, thereby increasing deposit formation. These findings highlight the significant influence of fuel characteristics and air supply on the thermal performance of diesel engines.

Keywords: B40, CPO, biodiesel, temperature, diesel engine

1. Introduction

The demand for energy supply is a major concern for all countries around the world. However, fossil fuels still dominate as the main source used to support daily activities in many nations [11]. The four sectors with the highest energy consumption include industry, transportation, households, and the commercial sector. Among these, transportation ranks second as the largest energy consumer, playing a vital role in meeting society's needs [1].

The transportation sector is largely dominated by diesel-powered vehicles due to their efficiency and longer travel range. However, dependence on fossil energy has become a serious problem as

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reserves continue to decline, leading to rising fuel prices. According to data from the Indonesian Ministry of Energy and Mineral Resources (2023), the country's petroleum reserves show a declining trend [12]. Therefore, solutions such as the development of alternative fuels [13][14] including biodiesel [15][16][17], bioethanol [18][19], biogas [20][21], biobutanol [22][23], and hydrogen [24][25] are urgently needed to sustain daily activities and economic operations. By utilizing renewable natural resources, these alternative energy sources are expected to reduce our dependence on fossil fuels [26] and help decrease greenhouse gas emissions that are harmful to the environment [2][3].

2. Material and Method

2.1 Biofuel

Biodiesel is a renewable energy derived from plant and animal oils and fats, with a chemical structure similar to diesel fuel [4]. Biodiesel utilizes renewable resources, unlike fossil fuels which are non-renewable and flammable [5].

The raw materials for biodiesel come from various sources, primarily oil-producing plants such as soybean, canola, olive, sunflower, castor bean, coconut, and palm oil, as well as used cooking oil and other sources [6]. Biodiesel's main advantages include its sustainability and environmentally friendly properties.

Crude Palm Oil (CPO) is used in various fields, one of which is as a raw material for biodiesel production a renewable biomass-based fuel. Crude palm oil is a vegetable oil obtained from processing oil palm fruit bunches (FFB). This oil is widely used in the food, cosmetic, and fuel industries. Indonesia is the world's leading producer of crude palm oil [7].

Crude palm oil is extracted from harvested oil palm fruits and has diverse uses, ranging from raw materials for cooking oil, margarine, soap, cosmetics, to biodiesel. Additionally, this oil serves as a renewable energy source in biodiesel production as an alternative to fossil diesel fuel.

Table 1 presents the characteristics of the fuel used in this study.

Table 1. Properties of B40 and CPO

Fuel Property	Unit	B40	CPO
Density	kg/m^3	857.1	933
Flash Point	˚C	88	251
Kinematic Viscosity	cSt	3.25	9,16
Cetane Number	-	53.6	37,52
Sulfur	ppm	820	130

2.2 Intenal Combustion

An internal combustion engine is a type of heat-generating engine in which the fuel combustion process takes place directly within the engine chamber, causing the resulting combustion gases to function as the working fluid [8]. The diesel engine, also known as a compression ignition engine, belongs to the category of internal combustion engines. In this engine, the fuel combustion process occurs inside the engine chamber by utilizing the heat from compression to ignite and burn the fuel injected into the combustion chamber [9].

2.3 Experimental setup and procedure

This study uses a diesel engine fueled by Crude Palm Oil (CPO) and B40 to analyze the effect of variations in the air-fuel ratio (AFR) on engine temperature. The experiment monitors several parameters, including the temperature of the cylinder block, cylinder head, intake pipe, exhaust pipe, and coolant tank.

The data collection process involves several stages: preparation and setup of equipment, pre-operation testing and calibration to ensure proper functionality, and data acquisition following established procedures to obtain accurate information. Each stage aims to maintain the quality of the experimental data. Additionally, supervision during testing is conducted to detect any disturbances or inconsistencies that may affect the results. After data collection, analysis is performed to evaluate the outcomes and draw conclusions according to the research objectives.

The study employs CPO and B40 fuels in a Kubota RD 65 DI-NB diesel engine connected to a Denyo FA 5 alternator. Pertamina SX Bio SAE 15W-40 lubricant and Prestone coolant are used. The engine and alternator are linked by three V-

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belts, producing 4000 watts of power to supply a halogen lamp load controlled by a panel. The CPO is heated to 100°C using a heater and mixer, with temperature monitored by a type-K thermocouple.

The engine trial is conducted to ensure the engine starts and operates stably under a 4000-watt load for 15 minutes. Engine speed and temperatures are monitored, and technical inspections are carried out before data collection begins.

Data acquisition is performed once the engine is ready for testing. Temperatures of the diesel engine components are measured at a 4 kW load with engine speeds of 1000 RPM and 2000 RPM. Fuel consumption is recorded for every 20 ml decrease in volume to maintain accuracy and consistency of the test results. Figure 1 illustrates the research scheme carried out in this study.

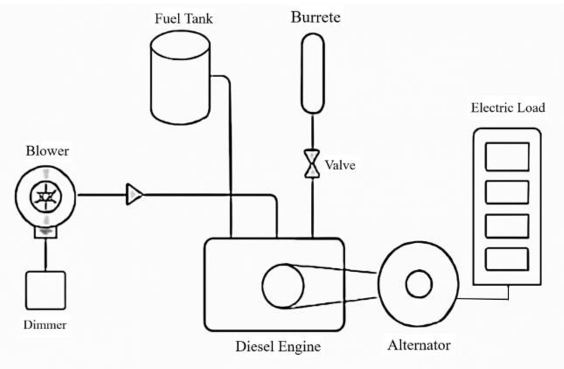

Fig. 1. Schematic diagram of the experimental setup

3. Results and Discussion

3.1 Temperature Cylinder Head

Based on the graph shown in Figure 2, the cylinder head temperature of the diesel engine at 1200 RPM gradually increases with the blower power rising up to 100%. This phenomenon likely occurs because the increased air supply leads to more complete combustion. Additionally, the temperature rise may also be influenced by the duration of engine operation. Meanwhile, off-grade CPO fuel produces higher temperatures compared to B40 fuel. On average, the temperature generated by the engine using off-grade CPO fuel is about 4.81% higher than that of the engine using B40 fuel. This difference may be caused by the higher oxygen content in off-grade CPO fuel compared to B40.

The engine operating at 2000 RPM produces higher temperatures than the engine at 1200 RPM. This is because the engine performs more work at 2000 RPM, resulting in higher temperatures. The cylinder head temperature at 2000 RPM also increases gradually along with the blower power reaching 100%. However, the temperature increase at the cylinder head below 2000 RPM is not as significant compared to the loading at 1200 RPM. This is evidenced by the lower standard deviation values at 2000 RPM, which are 4.25 for off-grade CPO and 3.13 for B40 fuel. These values are significantly lower compared to those at 1200 RPM, which are 5.65 for off-grade CPO and 4.62 for B40 fuel. Factors that may influence the cylinder head temperature include engine performance parameters such as load and engine RPM. As load and RPM increase, the cylinder head temperature tends to rise.

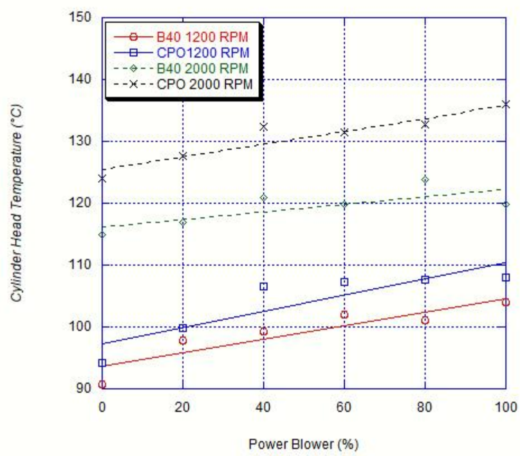

Fig. 2. Cylinder head temperature graph at 1200 and 2000 RPM

3.2 Temperature Cylinder Block

The trendline shown in the graph in Figure 3 indicates an increase in the temperature received by the engine's cylinder block for both off-grade CPO and B40 fuels. This temperature rise occurs alongside the increase in blower power up to 100% at 1200 RPM. The temperature increase at each blower power level is relatively high, with a standard deviation of 4.84 for B40 fuel and 4.89 for off-grade CPO fuel. The temperature produced by the engine using off-grade CPO fuel is 8.47% higher compared to the engine using B40 fuel. The highest cylinder block temperature was recorded at 100% blower power, with an average value of 104.1°C for off-grade CPO and 98.8°C for B40 fuel.

The graph in Figure 3 also shows an increasing trend for the engine operating at 2000 RPM as blower power rises. The increase observed at 2000 RPM is significant, with standard deviations of 6.31 for B40 and 5.48 for off-grade CPO. This is due to improved engine performance and longer operation time. Off-grade CPO fuel produces higher temperatures compared to B40 at all blower power levels. The highest recorded temperatures were 132.1°C for off-grade CPO and 120.6°C for B40. The higher oxygen content in off-grade CPO significantly affects the temperature generated in the diesel engine. Additionally, the high viscosity of off-grade CPO fuel causes larger fuel droplets, resulting in incomplete combustion. Unburned fuel droplets cause most of the heat generated during the compression process to be wasted.

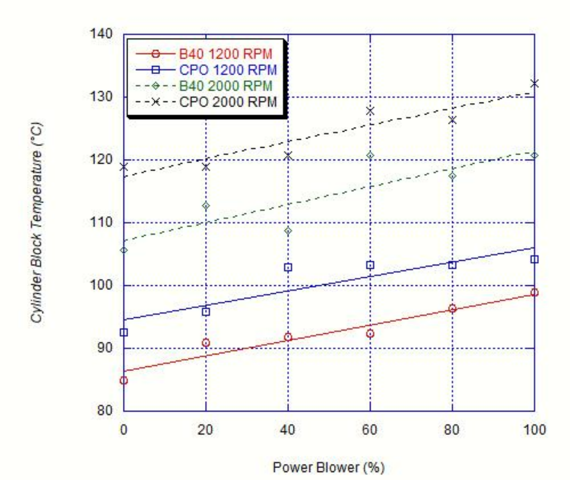

Fig. 3 Cylinder block temperature graph at 1200 and 2000 RPM

3.3 Temperature Intake Pipe

As shown in the graph in Figure 4, the intake pipe temperature exhibits a decreasing trend as blower power increases. At 1200 RPM, the engine fueled with off-grade CPO produces an average temperature that is 10.16% higher compared to the engine fueled with B40. The highest temperatures for both fuels are recorded when blower power reaches 100%. For the engine using off-grade CPO, the peak temperature reaches 58.6°C, while the engine fueled with B40 attains a maximum temperature of 52.5°C. The temperature increase at 2000 RPM is quite significant, with standard deviations of 2.16 for off-grade CPO and 2.31 for B40.

The intake pipe temperature at 2000 RPM is higher for both off-grade CPO and B40 fuels. The trend also shows a decrease as blower power rises up to 100%.

The decrease in temperature in the diesel engine's intake pipe with increasing airflow from the blower is caused by two main factors. First, higher air velocity enhances convective cooling efficiency, where air more quickly absorbs and removes heat from the pipe walls. Second, the increased air volume means a larger air mass can distribute existing heat over a wider area, resulting in a lower average measured temperature. Additionally, cooler air entering the combustion chamber helps reduce the overall engine temperature. This also contributes to improved combustion efficiency and reduced exhaust emissions.

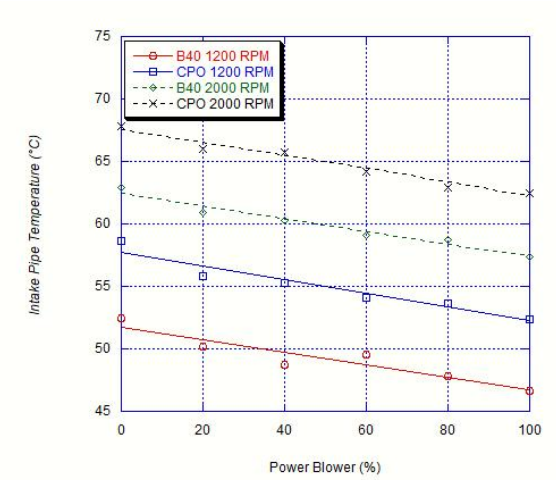

Fig. 4 Intake pipe temperature graph at 1200 and 2000 RPM

3.4 Temperature Exhaust Pipe

As shown in the graph in Figure 5, the exhaust pipe temperature exhibits an increasing trend with rising blower power. At 1200 RPM, the engine fueled with off-grade CPO produces an average temperature 6.68% higher than that of the engine fueled with B40. The highest temperatures for both fuels are recorded when the blower power reaches 100%. For the engine using off-grade CPO, the peak temperature reaches 176.4°C, while the engine fueled with B40 attains a maximum temperature of 161.2°C. The temperature increase at 2000 RPM is quite significant, with standard deviations of 3.74 for off-grade CPO and 3.52 for B40.

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The exhaust pipe temperature at 2000 RPM is higher for both off-grade CPO and B40 fuels. The trend also shows an increase as blower power rises up to 100%.
The higher exhaust pipe temperature in the engine using off-grade CPO compared to B40 can be attributed to several factors. Off-grade CPO has inferior characteristics compared to B40, primarily due to its higher kinematic viscosity, which leads to less efficient atomization and the formation of larger fuel droplets that are more difficult to burn. Additionally, larger droplets contribute to incomplete combustion, resulting in higher deposit formation. These deposits act as insulators, causing more heat to be retained inside the exhaust pipe, thereby increasing the temperature. Similar findings were also reported by Buyukkaya [10]. Deposits are not only found in the exhaust pipe but also in the combustion chamber, piston, intake valves, exhaust valves, injectors, and cylinder head, leading to an overall increase in temperature.

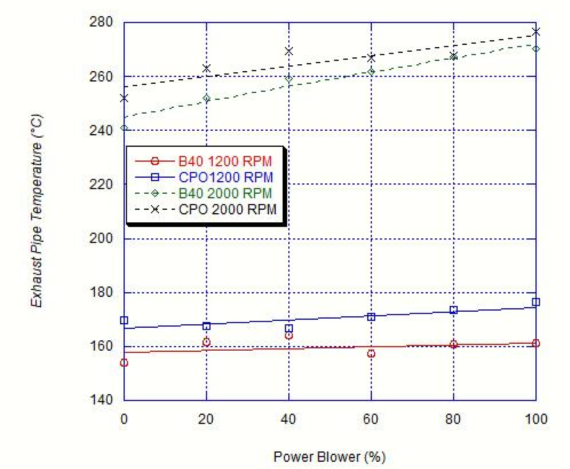

Fig. 5 Exhaust pipe temperature graph at 1200 and 2000 RPM

3.5 Temperature Coolant Tank

As shown in the graph in Figure 6, the coolant tank temperature exhibits an increasing trend with rising blower power. At 1200 RPM, the engine fueled with off-grade CPO produces an average temperature 5.81% higher than that of the engine fueled with B40. The highest temperatures for both fuels are recorded when blower power reaches 100%. For the engine using off-grade CPO, the peak temperature reaches 44.8°C, while the engine fueled with B40 attains a maximum temperature of 43.2°C. The temperature increase at 2000 RPM is quite significant, with standard deviations of 1.76 for off-grade CPO and 1.22 for B40.

The coolant tank temperature at 2000 RPM is higher for both off-grade CPO and B40 fuels. The trend also shows an increase as blower power rises to 100%.

The rise in coolant tank temperature alongside increased airflow from the blower in the diesel engine can be explained by several processes. The increased air supply from the blower optimizes fuel combustion inside the engine, generating greater heat energy release. This excess heat is then absorbed by the coolant circulating through the engine block and cylinder head. As this hotter coolant flows back into the cooling system, including the coolant tank, the overall coolant temperature rises, causing the temperature of the tank to increase.

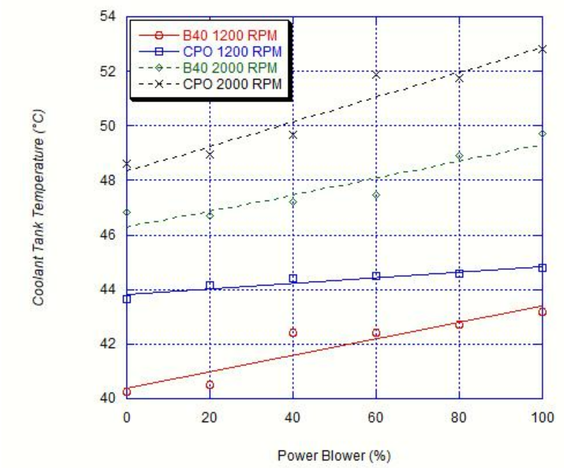

Fig. 6 Coolant tank temperature graph at 1200 and 2000 RPM

4. Conclusions

Experimental data consistently show that increasing blower power up to 100% causes a gradual rise in temperatures across various engine components, such as the cylinder head, cylinder block, exhaust pipe, and coolant tank, at both 1200 and 2000 RPM. However, a decrease in temperature is observed in the intake pipe, which is attributed to the increased air velocity enhancing convective cooling efficiency—where air absorbs and removes heat from the pipe walls more quickly—as well as the increased air volume, meaning a larger air mass can distribute heat over a wider area, resulting in a lower average measured temperature.

Engines operating at 2000 RPM consistently produce higher temperatures compared to those at 1200 RPM, due to the greater mechanical workload generating more heat.

Under all test conditions, engines fueled with off-grade CPO exhibit higher temperatures than those fueled with B40. On average, off-grade CPO causes temperature increases of approximately 4.81% in the cylinder head, 8.47% in the cylinder block, 10.16% in the intake pipe, 6.86% in the exhaust pipe, and 5.81% in the coolant tank compared to B40. This temperature rise is mainly due to the higher oxygen content and viscosity of CPO, which results in larger fuel droplets, incomplete combustion, and increased deposit formation. These deposits act as thermal insulators, particularly in the exhaust pipe, leading to elevated localized temperatures.

Deposit formation not only affects the exhaust system but also accumulates in the combustion chamber, piston, intake and exhaust valves, injector, and cylinder head, collectively causing an overall increase in engine temperature. These findings underscore the significant influence of fuel characteristics, engine load, and blower power on the thermal performance of diesel engines.

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