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Study on Performance and Emission of Diesel Engine Using Palm Oil Biofuel-Diesel Blends

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ABSTRACT

The addition of biofuel to diesel increases the fuel's stability, density, viscosity, energy content, and cetane number Blending biodiesel and diesel improves the viscosity of the combined fuel in comparison to diesel fuel. Recently, studies on optimizing the use of biodiesel diesel fuel have begun to examine the effects on diesel engine components and the energy conversion efficiency of biodiesel fuel use. The addition of supplements from other natural fuels is an effective option to improve energy conversion efficiency, but the blending effect causes changes in fuel properties. Therefore, further analysis is needed to meet the fuel standards used in diesel engines. This study is to obtain a clearer analysis of the effect of biofuel addition on diesel engine performance and exhaust emissions. Measurements of experiment variables such as Torque, thermal efficiency, power, bsfc, and gas emission obtained from sensors installed in each part of the laboratory scale of diesel engine. The result shows blends of biofuel and diesel can be used as alternative fuels in conventional diesel engines. The variation of power generated by both of fuel mixture shows average power without any major changes. The thermal efficiency of 30% biofuel average is better across all engine speed variations whereas the carbon monoxide variation decreases towards the same amount at 3000 rpm.

Keywords: *Biodiesel, Gas Emission, Diesel Engine, Unburn Fuel,*

1. INTRODUCTION

Diesel engines have been used in various industries such as agriculture, transportation, and power plant, due to high efficiency of the engine. In addition, the increasing of the diesel engines usage, required more petroleum fuel than ever. On the other hand, it is also now generally recognized that the world's petroleum energy resources are depleting, so many studies have been conducted to find suitable alternative fuels to petroleum products [1]. According to Syam, et al. [2], triglycerides found in plant oils can be converted into FAME to produce biodiesel with qualities that fulfil standard biodiesel criteria. This has been the focus of numerous investigations to produce biodiesel from various plant sources.

The addition of biofuel to diesel increases the fuel's stability, density, viscosity, energy content, and cetane number [3]. Blending biodiesel and diesel improves the viscosity of the combined fuel in comparison to diesel alone. The more viscous nature of the biodiesel-diesel blend influences the fuel injection process into the cylinder, resulting in incomplete combustion, which reduces the diesel engine's conversion efficiency and increases emissions. The use of various types of fuel mixtures in diesel engines is still the focus of researcher's efforts to optimize the use of alternative fuels as the main energy source in energy conversion machines and reduce dependence on fossil fuels. Biofuels such as biodiesel and bioethanol are becoming a global concern to be used as a substitute for fossil fuels.

Recently, studies on optimizing the use of biodiesel diesel fuel have begun to examine the effects on diesel engine components and the energy conversion efficiency of biodiesel fuel use. The addition of supplements from other natural fuels is an effective option to improve energy conversion efficiency, but the blending effect causes changes in fuel properties. Therefore, further analysis is needed to meet the fuel standards used in diesel engines. Fuel blending tests on components confirmed that ethanol-biodiesel-diesel fuel mixtures have similar effects on injection pump durability [4]. The influence on performance has also been tested experimentally, with the addition of 10% biodiesel to a blend of 20% ethanol and 70% diesel fuel generating positive results, with thermal efficiency increasing due to more stable combustion than pure diesel fuel. The addition of biodiesel to ethanol-diesel resulted in the blended fuel's physical and chemical qualities approaching those of pure diesel fuel [5].

A study using diesel engines and the Virtual Engine Simulation Tool AVL Boost was conducted by [6], adding ethanol with a 10% concentration into diesel fuel. Simulations were conducted at engine rotation speeds of 1000–1500 rpm with loads up to 60 N.m. The analysis results showed a decrease in CO, soot, and NOx emissions. On the other hand, experiments have been conducted comparing the addition of ethanol and methanol as additives to biodiesel-diesel blends, and the results shows the specific fuel consumption of ethanol was better than methanol, and NO emissions were reduced while CO and HC emissions increased [7]. Reduced CO and NOx emissions were also reported by Krishna et al., 2019. The increasing of cylinder pressure to 4.1% and a maximum heat release of 13.7% in a test with an engine rotation speed of 750 rpm with a loading of 40 N.m. were obtained at a concentration of 3% ethanol addition [8].

Ethanol is a short-chain alcohol that can replace diesel fuel for operation in diesel engines [9]. The use of bioethanol as a supplement in diesel engines has been widely practiced and has a positive effect on engine performance [10]. These phenomena due to 35% oxygen content in bioethanol, which allows for more complete combustion [6]. However, high ethanol concentrations of more than 8% (D92E8) in diesel fuel increase ignition delay and increase engine performance irregularities [11]. In addition, biodiesel-bioethanol-diesel blends improved auto ignition delay and combustion pressure and reduced CO and NOx emissions [4]. CO emissions were reduced by 43% or 2.4 g/kWh, and NOx emissions decreased by 20% with the addition of ethanol [12]. Ethanol hydrate with variable water content was also used in the other experiments. The results showed that the water content of ethanol can affect the auto ignition time, and large concentrations of ethanol in diesel increase the ignition delay time and decrease the combustion speed. However, at ethanol concentrations of 7.5% and above, the ignition duration tends to decrease as the water content increases. This result shows that the water contributed to the auto ignition inhibitor [13]. The high water content of ethanol might lower the temperature of the flame [14].

Increasing the concentration of biofuels, comparable to that of fossil fuels, is one technique for increasing the usage of biofuels as an energy resource while decreasing reliance on fossil fuels (Asad et al., 2022). The concentration of biofuel use was increased up to 40% with a 2.5% biofuel concentration interval, according to the study [5]. This study is to obtain a clearer analysis of the effect of biofuel addition on diesel engine performance and exhaust emissions. This information is useful for diesel engine performance studies in determining other suitable and optimum additives in the sustainable use of biodiesel fuel in the future.

2. METHOD

This study using a standard laboratory diesel engine was conducted using computer-integrated test equipment consisting of a diesel engine, an eddy current dynamometer, and a gas analyzer, as shown in figure 1. The specifications of the diesel engine used in this test are shown in Table 1.

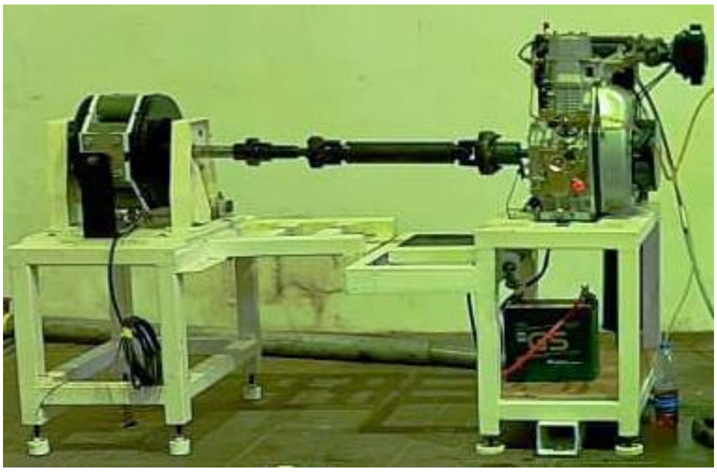


Figure 1 Diesel engine test bed

In addition, the eddy current dynamometer was equipped with the engine test bench to record the performance metrics, including torque, braking force, specific fuel consumption, and thermal efficiency. All tests were run under full load in range of 1000-3500 rpm. Measurements of other variables such as temperature, pressure, air flow, and fuel consumption obtained from sensors installed in each part of the diesel engine are recorded in real-time with a personal computer that has been connected to the MyRio microcontroller using the LabView software interface. Data from sensors is recorded with a data record interval of 0.5 seconds per data point.

Table 1 Specification of diesel engine.

Parameters	**Value**
Engine Type/Model	4 Stroke, Vertikal, direct-injection/186FA
Displacement	418 cc
Bore x Stroke	86 x 72 mm
Power Output	6,3 kW @ 3600 Rpm
Mean speed of piston	864 m/s @ 3600 Rpm
Mean effective Pressure	502,4 kPa
Specific fuel consumption	≤ 281,5 g/kW.h
Cylinder	*Single* cylinder
Fuel	Diesel

The concentration of adding up to 10% biofuel by volume fraction to the biodiesel-diesel blend with the concentration of each fuel is designated as B30, which is a blended fuel with a concentration of 30% biodiesel and 70% diesel produced and marketed in Indonesia by Pertamina or called Biosolar (B30). B40 is obtained by adding pure biofuel concentration to B30 based on volume fraction. The concentrations of the various blends are shown in Table 2.

Tabel 2 Concentration of fuel mixture

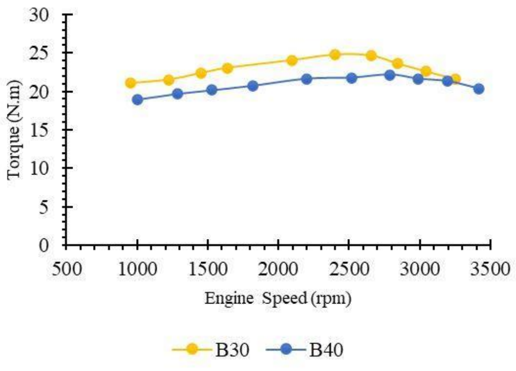
Fuel Code	Diesel (Vol%)	FAME (Vol%)
B30	70	30
B40	60	40

Emission production from each fuel mixture was carried out at a variety of engine rotation speeds, from 1000 rpm to 3500 rpm, with an interval of 500 rpm for each test. To obtain accurate data, each fuel test engine rotation speed was maintained at a certain speed for 5 minutes. Exhaust gas from the diesel engine distributed through a probe connected to a calibrated gas analyzer. The emission test results of each fuel mixture were evaluated, including those for carbon monoxide (CO), and hydrocarbons (CxHy) emission to obtain the unburning fuel. The data used for analysis is the average, where the level of measurement stability is achieved at each fuel variation and engine rotation speed.

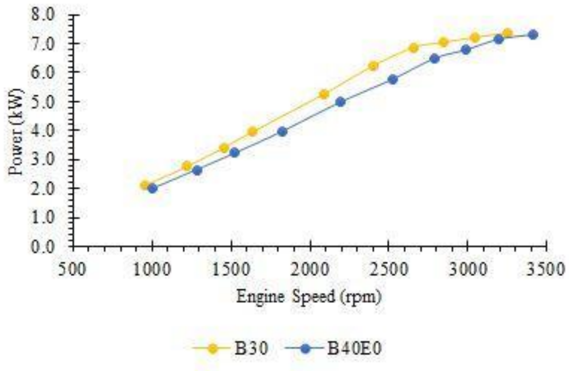
3. RESULTS AND DISCUSSIONS

3.1. Performance of Diesel Engine

The effect of the biofuel-diesel blend on the engine torque and power of the various engine speed are shown in Figure 2. As seen in Figure 2, at all engine speeds, biofuel concentrations (B30 and B40) produced torque that is most comparable. In comparison to B30, the torque profile caused by the addition of palm oil biofuel generally causes a reduction in torque. Figure 2(a) shows the variation of torque for B30 and B40 that increasing up to 2500 rpm engine speed. The B30 biofuel mixture shows more higher as 6.3% compared to B40. Comparison of biofuel concentration, combustion happens more reliably at high speeds in the B30 fuel mixture generating more power.



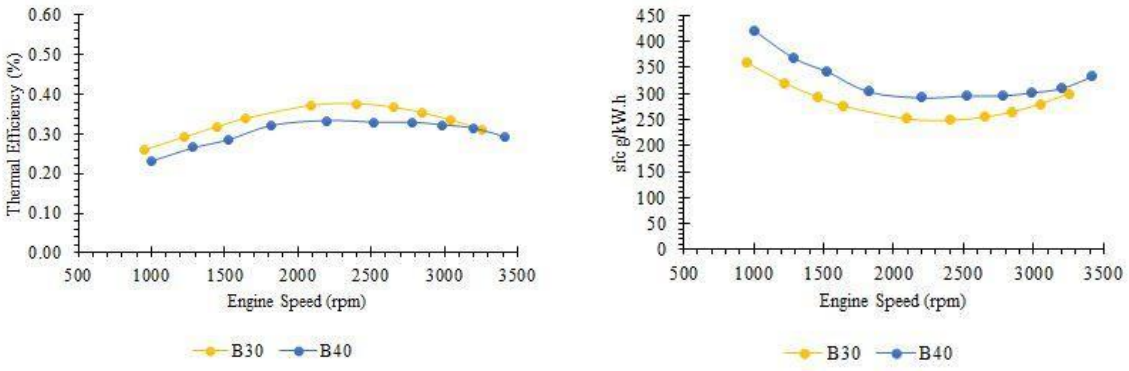
(a)



(b)

Figure 2 (a) Variation of torque (N.m) and engine speed, (b) Variation of power (kW) and engine speed.

Brake specific fuel consumption (bsfc) is a measure of the efficiency by chemical energy conversion of the fuel to produce engine power [15]. According to Figure 3, the bsfc for all fuel combinations decreases with increasing engine speed up to 3500 rpm and then rises at higher speeds. The diesel engine's energy conversion efficiency increases with decreasing BSFC. The increase is brought on by greater power losses at faster engine rotation speeds [16].



(a) (b)

Figure 3 (a) Variation of thermal efficiency and engine speed (rpm) (b) Variation of specific fuel consumption (g/kW.h) and engine speed (rpm).

Figure 3 (a) shows the comparison of the brake thermal efficiency with engine speed for the tested fuels. The graph shows increasing of thermal efficiency for both of fuel mixture as increasing engine speed up to 2500 rpm. The 30% of biofuel concentration generated high thermal efficiency compared to 40% biofuel concentration, due to the lower heating value and inferior combustion of biodiesel. Figure 3(b) shows decreasing bsfc as increasing engine speed up to 2500 rpm, and it increases again at higher speeds for all fuel mixtures. The lower the bsfc is obtained, the higher the energy conversion efficiency of the SI engine. The increase in bsfc is caused by friction losses at a higher rotational speed of the engine [16]. The highest bsfc was obtained from a 30% concentration of biofuel. On the other hand, the 40% of biofuel concentrations of required higher fuel mass to generate the engine power at the same engine speed due to the low energy content in biofuel [17].

3.2. Effect of Biofuel on Gas Emissions

The phenomenon of increasing the percentage of carbon dioxide at all fuel mixture concentrations in line with engine rotation speed shows that the addition of biofuel influences diesel engine exhaust emissions. The highest percentage difference is at concentration B40 which shows a percentage change of 6.2% at 3000 rpm engine speed. In addition, the percentage of unburned fuel is determined by the concentration of the fuel mixture and the variation of engine rotation speed. The fuel blends without the addition of bioethanol, B30 and B40, showed a tendency to decrease the percentage of unburned fuel at all engine output speeds. The decreasing value of unburned fuel in both fuel blends indicates a change in performance and emissions produced by diesel engines.

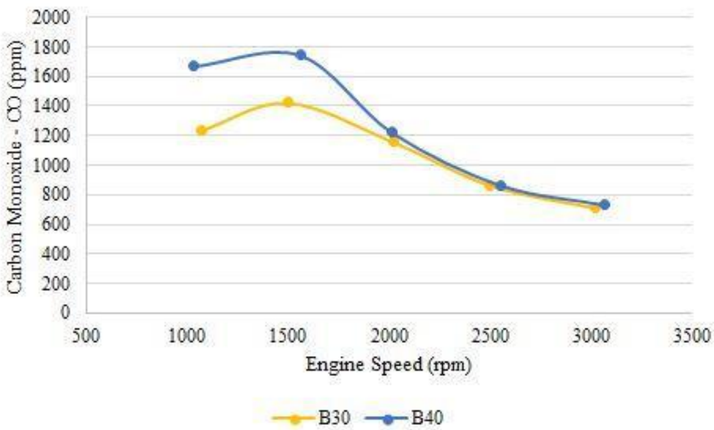


Figure 4 Variation of carbon monoxide and engine speed

Figure 4 shows that the amount of carbon monoxide decreases with increasing engine speed due to the addition of biodiesel. At 3000 rpm, the amount of carbon monoxide produced tends to decrease toward the same amount in both fuel blends.

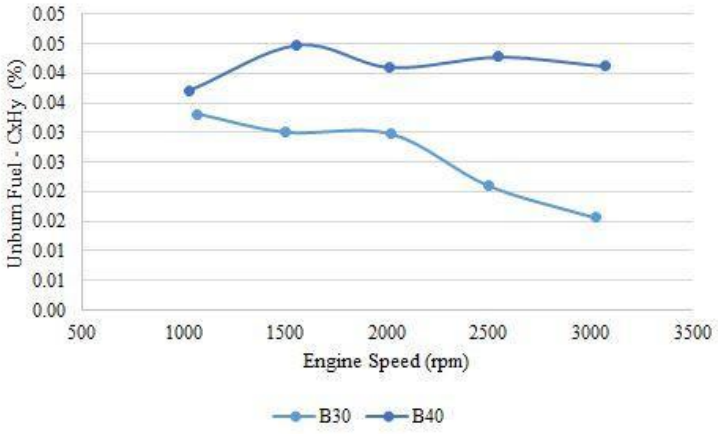


Figure 5 Variation of unburn fuel and engine speed

Furthermore, Figure 5 shows the potential of incomplete combustion, where the B30 and B40 fuel mixes have a propensity to reduce the percentage of unburned fuel at all engine output speeds. The decreasing value of unburned fuel in both fuel blends reflects a shift in diesel engine performance and emissions.

4. CONCLUSSION

Blends of biofuel and diesel can be used as alternative fuels in conventional diesel engines. The torque of engine obtained for B30 was higher than B40 fuels. The variation of power generated by both of fuel mixture shows average power without any major changes. The thermal efficiency of 30% biofuel average is better across all engine speed variations. The carbon monoxide variation decreases towards the same amount at 3000 rpm due to the high turbulence in the cylinder, so that the homogeneity of the fuel-air mixture increases in B30 and B40.

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