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Effect of Power and Mix Fuel Used Oil and Pertamina Dex on Exhaust Gas Emissions from Modified Diesel Engines

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ABSTRACT

Industrial growth and the increasing number of transportations cause the need for oil to increase. The increasing need for oil is directly proportional to the waste produced, namely used oil. Used oil waste can be a replacement fuel, which is produced quite large every year. This research used a mixture of used oil and Pertamina Dex used as a modified diesel engine fuel. The purpose of this study was to analyze the exhaust emissions produced by modified diesel engines. The research was conducted by varying the percentage of the mixture of used oil and Pertamina Dex, namely the percentage of a mixture of P10 (90% used oil and 10% Pertamina Dex), P20 (80% used oil and 20% Pertamina Dex) and P30 (70% used oil and 30% Pertamina Dex). Tests on the calorific value of fuel and exhaust emissions, which are varied based on the power load at idle (0 W), 1,000 W and 2,000 W. The test results showed that the calorific values of fuel P10, P20 and P30 were 44,191 kJ/Kg, 48,648 kJ/Kg and 50,074 kJ/Kg respectively. From this research it is known that the best fuel mixture of P30 with a loading power of 0 W, which emits a value of CO of 0.03%, CO_2 of 2.32%, and HC of 34.86%. The results showed that the P10, P20 and P30 fuels met the exhaust emission quality standards according to the applicable regulations where the resulting opacity emissions did not exceed 40%.

KEYWORDS: *Engine, Exhaust gas emission, Pertamina Dex, Used oil.*

1. INTRODUCTION

Technological developments occur every year, one of which is in the automotive sector. Almost all people use automotive technology every day, such as vehicles of various types including cars, motorbikes, and others [1]. One impact of the increasing number of motor vehicles is the increasing amount of used oil. Used oil or lubricating oil is a liquid used by motor vehicles as engine oil. Oils aim to minimize friction between surfaces in the engine [2]. Every vehicle with a combustion engine uses oil, so the amount of oil used is the same as motor vehicles [3]. Based on data by Indonesia Traffic Corps, the number of vehicles in Riau Province in 2024 was amount to 3,580,735 Unit [4]. Motorized vehicles require around 1 to 12 liters of oil with the highest oil consumption in the type of bus and truck vehicles [5]. If it is assumed that motorized vehicles require 2 liters of oil, so that in 2024 the used oil produced was 71,614,670 liters.

So far, used oil has only been collected for disposal or simply burned [6]. However, used oil can actually still be reused. This can help minimize the limited supply of energy sources by utilizing alternative fuels derived from waste [7]. Used oil, which is classified as hazardous waste by Indonesian Government, has the potential to cause environmental damage if not managed properly. The increasing number of motor vehicles also results in increased exhaust emissions [8]. Motor vehicles that produce exhaust emissions are a form of pollutant that can degrade environmental quality and have negative effects on humans [9].

Previous research used oil as a fuel source for a modified Dongfeng R175 diesel engine. In the study by [10], the use of used oil as a fuel source for a diesel engine can be applied without any special processing. This diesel engine has a higher efficiency level than diesel engines using biodiesel. The volumetric efficiency of used oil is 51.6365%, slightly higher than that of biodiesel, which is 51.6316%. Another Research conducted by [11] that tested exhaust emissions on a Dongfeng R175 diesel engine with a standard opacity value of 40% using a mixture of used oil and *Dexlite* as fuel. The study found that emissions from used oil fuel alone exceeded the standard quality parameters, while a 90:10 mixture of used oil and Dexlite did not exceed the standard quality parameters. A study that tested emissions from a modified diesel engine using biodiesel fuel yielded similar results, with a 90:10 mixture of used oil and biodiesel yielding the best results [11]. Mixture of used oil and diesel fuel with a content of 5% to 40% resulted in an opacity value (λ) below 70% for 4-stroke diesel engines [12]. The types of fuel oil available for diesel engines include

Biodiesel, *Dexlite*, and Pertamina Dex.

Based on fuel quality, Pertamina Dex has the highest quality compared to other types of fuel, namely biodiesel and *Dexlite*. According to [13], Pertamina Dex is recommended for modern, high-tech diesel engines. Pertamina Dex has a cetane number of 53, meeting the EURO 4 standard, offering advantages, including low emissions. Therefore, exhaust emissions testing is required by varying the mixture of used oil and Pertamina Dex to achieve emissions that do not exceed the quality standard.

2. METHODS

2.1 Research Tools and Materials

Some of the equipment used in this study included a gas analyzer, a modified Dongfeng R175 diesel engine, and a bomb calorimeter. The materials used in this study were used oil and Pertamina Dex. The used oil was obtained from a motorcycle repair shop located on Pahlawan Kerja Street, Pekanbaru City. Pertamina Dex was obtained from a gas station located on SM Amin Street.

Figure 1: Modified diesel engine

2.2 Research Variables

The research variables were variations in used fuel oil mixed with Pertamina Dex, namely: 90% used oil and 10% Pertamina Dex (P10), 80% used oil and 20% Pertamina Dex (P20), and 70% used oil and 30% Pertamina Dex (P30). The load power variations were at idle (500 rpm), 1,000 W (1,400 rpm), and 2,000 W (1,700 rpm). RPM values were obtained by measuring with a tachometer. The fixed variables in this study were the exhaust gas emission parameters, namely CO, CO_2, HC, and Opacity (λ).

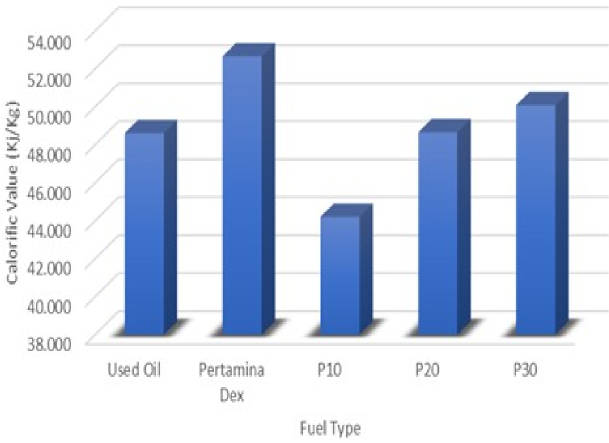
2.3 Calorific Value Testing and Measurement of CO, CO_2, HC, and Opacity (λ) Emissions

The research variables were variations in used fuel oil mixed with Pertamina Dex, namely: 90% used oil and 10% Pertamina Dex (P10), 80% used oil and 20% Pertamina Dex (P20), and 70% used oil and 30% Pertamina Dex (P30). The load power variations were at idle (500 rpm), 1,000 W (1,400 rpm), and 2,000 W (1,700 rpm). RPM values were obtained by measuring with a tachometer. The fixed variables in this study were the exhaust gas emission parameters, namely CO, CO_2, HC, and Opacity (λ).

3. RESULT AND DISCUSSION

3.1 Calorific Value of Mixed Fuels

The calorific value of the mixed fuel, used oil and Pertamina Dex, tested using a bomb calorimeter, is shown in Figure 2.



Description:
P10 = 10% Pertamina Dex and 90% Used Oil
P20 = 20% Pertamina Dex and 80% Used Oil
P30 = 30% Pertamina Dex and 70% Used Oil

Figure 2: Stern hull designs for podded propulsion system

Figure 2 shows that Pertamina Dex has the highest calorific value when compared to used oil and three other fuel mixture variations. Among the mixture variations of used oil and Pertamina Dex, the highest calorific value is in P30 fuel at 50,074 kJ/Kg and the lowest calorific value is in P10 fuel mixture at 44,191 kJ/Kg. This is because the higher the temperature increase (ΔT) of the fuel mixture sample, the higher the calorific value of the fuel mixture [14].

3.2 Fuel Consumption

The fuel consumption of used oil and Pertamina Dex used during testing varied by power can be seen in Figure 3 below. It shows that fuel consumption tends to increase as the power output increases. The P30 fuel mixture, with a power output of 2000 watts, consumed the most fuel, at 370 ml, while the P10 fuel mixture with a power output of 0 watts consumed the least fuel, at 180 ml. Test results show that fuel consumption increases with the given power load, because higher engine speeds also increase the turbulence of incoming air [15]. Fuel-air mixing improves with increasing engine compression [16]. Furthermore higher engine speeds increase fuel consumption, as the amount of fuel drawn into the cylinder increases during higher speeds [17].

The P30 fuel mixture uses more fuel than the P10 and P20 fuel mixtures. This is because the calorific value is inversely proportional to fuel consumption. A higher calorific value indicates lower fuel consumption [18]. It is also known that the amount of power used is correlated with the amount of fuel consumed. At high cylinder speeds, the mass of fuel sucked in along with the air entering the cylinder increases [19].

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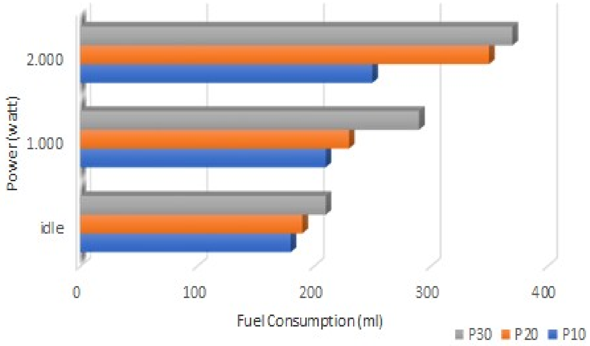

Figure 3: Stern hull designs for podded propulsion system

3.3 Diesel Engine Exhaust Emission Analysis

CO Emissions

The average CO emissions test results over a 30-minutes period is shown in Figure 4. Based on Figure 4, which shows the average carbon monoxide (CO) content of a modified diesel engine, the average CO emissions produced by the modified diesel engine fluctuate and tend to decrease with the addition of Pertamina Dex to the used oil. In his research, [20] explained that fuel must be mixed quickly with high-pressure air to achieve complete combustion. Fuel combustion is influenced by the amount of oxygen in the air; the greater the oxygen content, the greater the energy produced due to complete combustion.

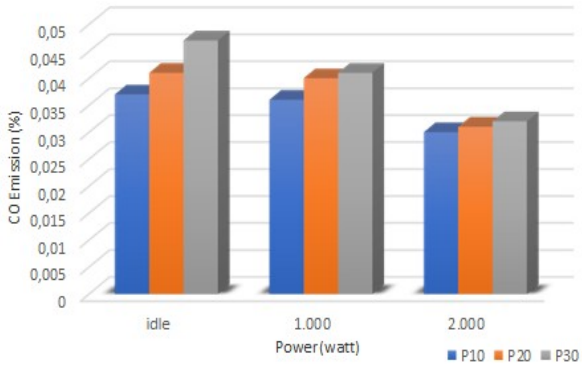

Figure 4: Average CO emissions

The CO content in the exhaust gas affects the amount of energy produced; the higher the CO content, the greater the energy loss. Excess air will affect the amount of energy produced from fuel combustion because excess air will absorb heat energy. Based on the results obtained, the lowest average CO gas emission value was found in the P30 mixture variation, namely 0.030% at a power load of 0 watts, 0.031% at a power load of 1000 watts and 0.0321% at a power load of 2000 watts.

CO_2 emissions

The average CO_2 emission test results can be seen in Figure 5. It shows the average CO_2 emission concentration. Increasing power causes an increase in engine rpm, which results in increased CO_2 emissions [21]. The highest CO_2 emissions were obtained in Variation P30, with values of 2.32% at 0 watts, 3.49% at 1,000 watts, and 4.77% at 2,000 watts.

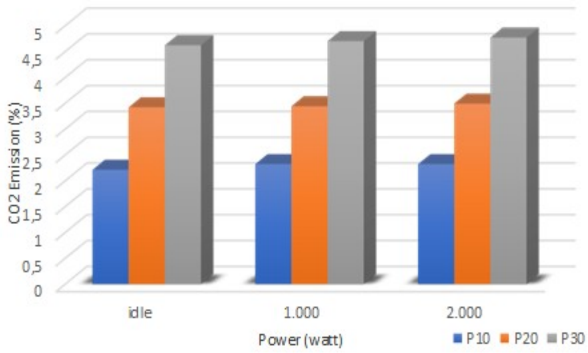

Figure 5: Average CO_2 emissions

Hydrocarbon Emissions

The results of the Hydrocarbon emission test, averaged over a 30-minute period, can be seen in Figure 6. It shows the fluctuating concentration value and the average Hydrocarbon tends to increase along with the power load. Hydrocarbon emissions come from various sources, which cause the fuel to not burn completely and the used oil not to burn in the cylinder [22]. HC is the same as CO, which is also the remaining unburned carbon due to insufficient temperature on the cylinder wall. The higher the Hydrocarbon value indicates that the combustion is increasingly imperfect [23]. The lowest HC emissions are found in the P30 mixture variation with an average emission value of 24.86 ppm at 0 watts, 28.14 ppm at 1,000 watts, and 32.71 ppm at 2,000 watts.

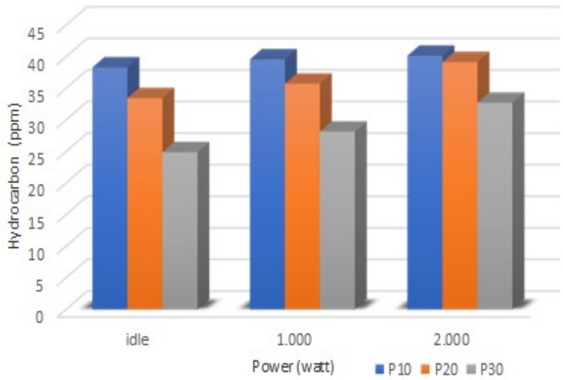

Figure 6: Average hydrocarbon emissions

Opacity (λ)

The results of Opacity emission test, averaged over a 30-minute period, can be seen in Figure 7. The opacity (λ) emitted by the modified diesel engine tends to increase as the power load increases. When the engine is idling, that is, operating without any power load, the opacity (λ) value is generally constant and does not increase significantly. The engine begins to receive a power load, the opacity (λ) value increases as the engine is operated. This result is in line with research by Majedy [24], which shows that the opacity (λ) value increases with the power load [24]. The results of the opacity (λ) value test on average decreased from the P10 to P30 variation. This result is also supported by research by [25] on Pertamina Dex producing a lower opacity. This is because the cetane value in Pertamina Dex is high, namely 53, so it can be burned

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completely and the resulting gas emissions do not contain impurities, causing lower opacity. Because of this, it can be concluded that increasing the mixing volume of Pertamina Dex in the used oil fuel variation and Pertamina Dex can improve its quality as a fuel. This decrease also occurred due to the low sulfur content in Pertamina Dex fuel. The sulfur content in Pertamina Dex fuel is <50 ppm, which meets Euro 4 standards [26].

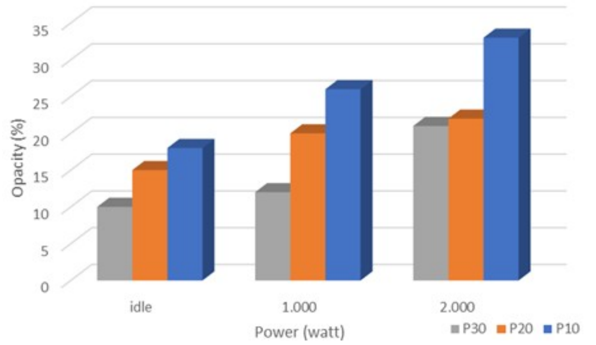

Figure 7: Average opacity (λ) emission

According to Minister of Environment Regulation No. 5/2006, the opacity standard is 40%. Modified diesel engines using a mixture of used oil and Pertamina Dex fuel in the P10, P20, and P30 variations showed that none of the opacity results exceeded the 40% standard.

4. CONCLUSION

The conclusion of this study is that the calorific value of fuel P10, P20 and P30 are 44,191 kJ/Kg, 48,648 kJ/Kg, and 50,074 kJ/Kg, respectively. The increasing power load issued by the diesel engine, the emission values of CO, CO_2, HC and opacity increase. From the exhaust emission test of the modified diesel engine with a mixture of used oil and Pertamina Dex fuel, the best mixture variation is P30 with CO, HC and CO_2 emissions of 0.03%, 38.57 ppm, and 3.53%. The three mixtures produce opacity values below the quality standard at all load powers with the largest opacity being 33% at a power load of 2,000 W. In each fuel mixture that is varied at each load power, the opacity value emitted is no more than 40%.

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