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# Performance and engine exhaust emissions in a mixture of pertamax with PET plastic oil

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**Abstract.** Public knowledge about plastic waste management is still a major problem. This study aims to determine the performance and engine emissions of a mixture of pet (p) and Pertamina (b) plastic oil, the purpose of which is to increase the RON of plastic oil. There were 3 fuels tested, pure plastic oil (p100), 90% Pertamina + 10% plastic oil (bp10), 80% Pertamina + 20% plastic oil (bp20). The highest torque test result was 11.38 nm at p100, the highest power was at bp20 with a value of 8.24 hp. exhaust gas emissions of CO = 4.33% at p100, and the best O<sub>2</sub> at 6.43% at rpm of 8500 with a mixture of bp20 fuel.

## 1. Introduction

The myriad of human mobility needs now has caused transport companies to compete to produce land, sea, and air transport. A form of transportation that Indonesians often use is a motorcycle. The number of motorcycles in Indonesia increases every year [1]. Increasing transport means increasing air pollution [2]. Therefore, it can be said that air pollution is directly proportional to the number of vehicles used by the people of Indonesia. Air pollution from vehicles is caused by incomplete combustion [3–5]. Mixing fuel with unbalanced air can cause incomplete combustion. Incomplete combustion can also be caused by the type of fuel with the octane number used that does not match the vehicle's compression ratio [6]. In Indonesia, the types of motorcycle fuel oil can be divided into three, namely Premium with an octane number of 88, Peralite with an octane number of 90, and Pertamina fuel with an octane number of 92. Pertamina has determined this as a fuel that can be used in general [7].

Pertamax is a fuel oil that uses the addition of additives which was issued in 1999, the successor to Premix98. With the element MTBE (Methyl Tetra Butyl Ether) Pertamina is one of the highly recommended fuels used in motor vehicles. The Pertamina prices sold in the market are higher than the Premium. In addition, Pertamina has a higher octane value than the premium [7,8].

Plastic is a type of macromolecule formed by the polymerization process. One type of plastic that can be recycled is PETE or PET (polyrthyleneterephthalate). PET is commonly used for clear plastic bottles, such as mineral water bottles, juice bottles, and almost all types of other beverage bottles. In addition to PET, there are types of HDPE (high-density polyethylene) plastic. HDPE is a type of plastic that is strong and rigid, derived from petroleum, which often forms when blown. HDPE can generally be found in milk bottles, medicine bottles, shampoo bottles, juice bottles, liquid soap bottles, and baby soap bottles. Plastic waste of various types has a negative impact on the environment [9]. One of the uses of plastic waste is to make it into fuel [10–13].

The purpose of this study was to determine the performance and exhaust emissions of engines using PET type plastic oil with a mixture of Pertamina. Mixing plastic oil with Pertamina aims to increase the



octane value of plastic oil so that it can be used for motorized vehicles. The fuels used included pure plastic oil (P100), 90% Pertamina mixture with 10% plastic oil (BP10), and 80% Pertamina mixture with 20% plastic oil (BP20). Another objective of this research is to use PET plastic waste as fuel.

## 2. Materials and methods

### 2.1. Material

Fuel engines have been used in human activities, as driving power in water pumps, generators, lawnmowers, or as a means of transportation to support the mobility of people and goods [7,8,14,15]. The combustion engine itself is divided into 2 (two) groups, namely gasoline and diesel engines. The difference lies in the fuel/air mixture ignition system, wherein the gasoline engine the fuel/air mixture is burned by sparks from the spark plug or often called the Spark Ignition Engine (SIE). According to [16], factors affecting engine performance include compression rates, air pressure, engine size, and temperature with the combustion process and the quality of the fuel. The result of engine performance is power, torque, fuel consumption.

The result of the combustion of a mixture of fuel and air released by the engine contains many gas components, most of the gas is pollution that is less friendly to the environment. Air pollution that endangers the environment occurs from incomplete combustion processes. Although the exhaust gases of motor vehicles mainly consist of harmless compounds like nitrogen, carbon dioxide, and water vents, They also contain a large number of other compounds that can harm exhaust gases and endanger the health and the environment. The pollutants that are mainly present in the exhaust gases of motor vehicles are carbon monoxide (CO), various subsequent hydrocarbon compounds, various oxides of nitrogen (NO<sub>x</sub>) and sulfur (SO<sub>x</sub>), and dust particles, including lead (PB) [17,18].

#### 2.1.1 Plastic oil fuel

Alternative fuel is an effort to reduce the type of fuel that is commonly used. This effort is certainly an alternative solution for how to reduce or use other alternative fuels. This does not mean that the use of the fuel is 100% pure. Usage is generally a comparison or mixture with the fuels used daily, if 100% pure alternative fuels are used, it is generally necessary to study further machine construction suitable for the use of these alternative fuel characteristics.

#### 2.1.2 Plastic PETE (POLYETHYLENE)

PETE plastic is one type of plastic that is generally used for clear bottles, such as cooking oil bottles and the like which, when used repeatedly, can remove carcinogens, especially in hot conditions. PETE plastic is recommended to be used once with used bottles and berets. Figure 1 below is a code for the type of plastic commonly used by the community.



**Figure 1.** Plastic code number.

### 2.2. Method

This research was conducted experimentally by comparing pure plastic oil fuel (P100) with 10% plastic oil fuel mixture and 90% Pertamina (BP10) and 20% plastic oil fuel mixture and 80% Pertamina (BP20). The properties of plastic oil are shown in table 1. This mixture of fuel oil and Pertamina was tested on a motorized vehicle with the specifications in table 2. Next, the 110 cc engine with plastic oil fuel and a mixture of plastic oil and Pertamina was tested for performance using dyno test with the specifications presented in table 3.

**Table 1.** Properties of plastic oil and plastic oil mixture with Pertamina.

Parameters	Limit	Results	
		Plastic Oil	20% Plastic Oil 80% Pertamina
Density at 15°C	715-770	750,7	742,6
Colour	Visual	Yellow	Green
Destilasi :			
-Initial Boiling Point (IBP)		65°C	45°C
-10%Vol.evap.		92°C	57°C
-50%Vol.evap.	ASTM D-86	-	92°C
-90%Vol.evap.		-	166°C
-F.B.P (End Point)		-	209°C
-Residu		-	1.3
Sulfur Content	ASTM D-4294	-	0,01
Octane Value	-	-	88,7

**Table 2.** Engine specifications.

Parameters	Description
Engine type	4-step SOHC engine with 2-valve, with air cooling.
Diameter and steps	50 × 55 mm
Step volume	108 cc (karburator)
Compression ratio	9,2 : 1
Maximum power	8,22 PS /8.000 rpm (carburetor)
Maximum torque	0,85 kgf.m/ 5.500 rpm (carburetor)
Gas tank capacity	3,5 liter (carburetor)
Spark plug type	NGK CPR8EA-9 atau Denso U24EPR9
Ignition system	DC-CDI
Carburetor type	Keihin AVK22 / throttle body 22 mm

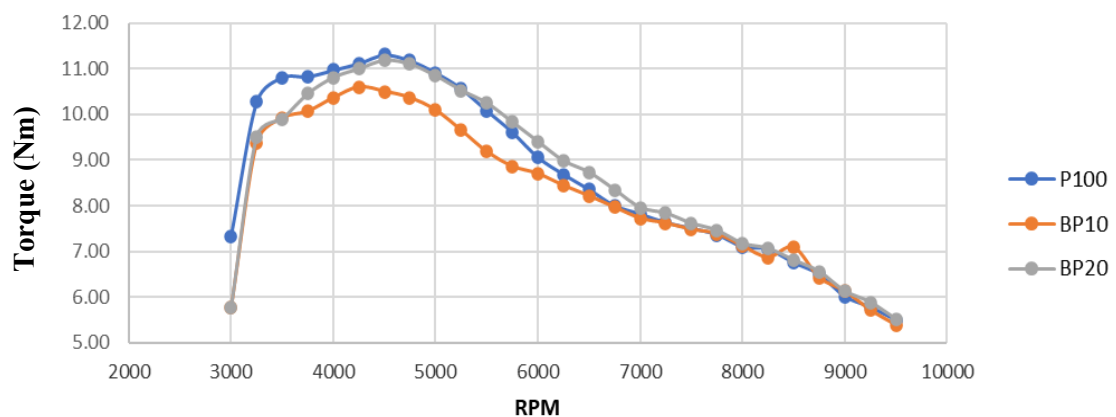
**Table 3.** Dyno test specifications.

Parameters	Descriptions
Measurement	Speed, Rpm, acceleration, torque, gears, and power
Data transfer	RS232 - USB
Maximum torque	50 Nm
Maximum RPM	20.000 rpm
Maximum power	50 Hp
Maximum speeds	350 km/hour
RPM measurement system	Induction
Torque measurement system	Load cell
Break type	Mechanical disk
Break control	Pneumatic 4 bar

Then the 110 cc engine with plastic oil fuel and a mixture of plastic oil and Pertamina exhaust gas emissions were also tested using dyno test with specifications such as table 4.

**Table 4.** Gas analyzer specifications.

Parameters	Measurement Range
CO	0.00 -10.00% vol
CO <sub>2</sub>	0.00 – 18.00% vol
HC	0 – 9999 ppm vol
NO	0.00 – 22.00% vol
O <sub>2</sub>	0 – 5000 ppm vol
Lambda ( $\gamma$ )	0.500 – 9.99
Rpm Counter	100 - 15000 rpm

**Figure 2.** Testing performance.**Figure 3.** Torque against RPM on P100, BP10, and BP20 fuels.

### 3. Results and discussions

Data were collected on torque and power using variations in rpm, namely 3000-9500 rpm (figure 2). From several variations in rpm, torque and power would be figured out. Using a certain type of fuel, this test was conducted 5 times to obtain maximum and specific data.

#### 3.1. Torque testing results

Based on figure 3, the torque generated from P100 plastic fuel oil at 3000-9500 rpm. Torque increases slowly until it reaches a peak of 4,500 rpm with an average torque of 11.30 Nm. From the BP10 fuel mix test results, the highest torque is at 4,250 rpm with an average torque of 10.60. When compared

with the results of testing for pure plastic fuel oil without mixture, the mixed fuel BP10 experienced an increase in torque by 6.6%. From the results of the BP20 mixed fuel test, the highest torque is at 4,500 rpm with an average torque of 11.18 Nm. When compared to pure plastic fuel oil without mixture, the mixed fuel BP20 has a torque increase of 1.07%. Based on the test results, it can be seen that the highest torque is achieved with P100 plastic fuel oil. This is because plastic fuel oil has a higher density compared to Pertamina and plastic fuel oil.

3.2. Exhaust emission test results

From several fuels that were tested using a gas analyzer, the ratio of exhaust gas emissions (CO, HC, CO<sub>2</sub>, O<sub>2</sub>) was found.

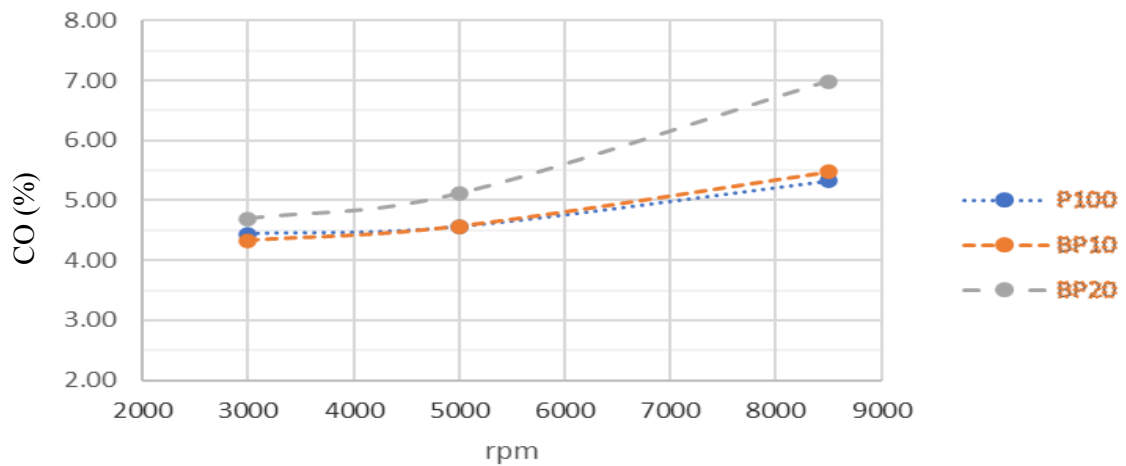


Figure 4. Comparison of exhaust emissions (CO) on fuel mixtures P100, BP10, BP20.

Figure 4 shows that the highest CO value is in the BP20 mixture of 6.98%, while the lowest performance is in the BP10 mixture with a value of 4.33% at 3,000 rpm rotation. The BP10 has a higher yield (5.5% at 8500 rpm) than the P100 because it is blended with alternative fuels. The smallest CO in the cheapest gasoline affects the mixture and the air.

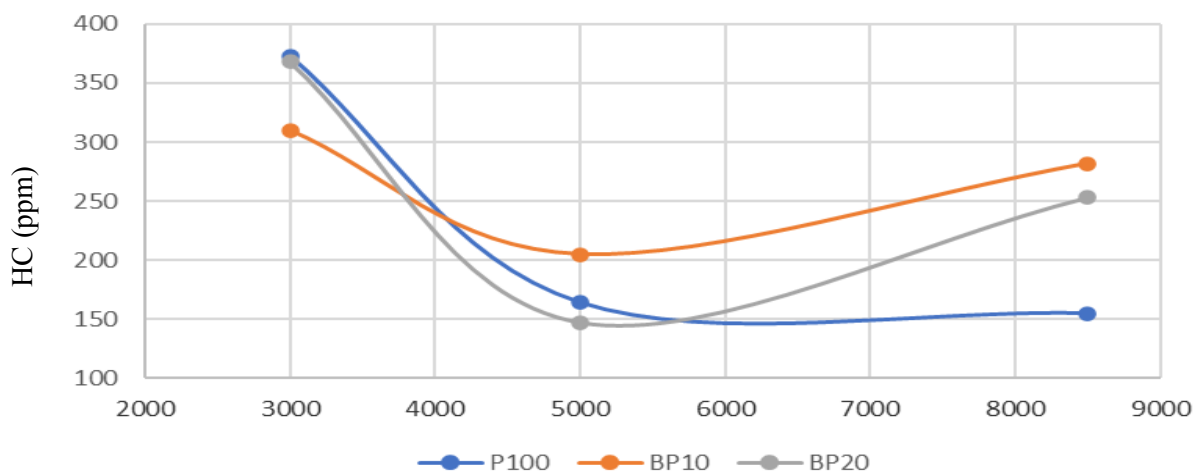
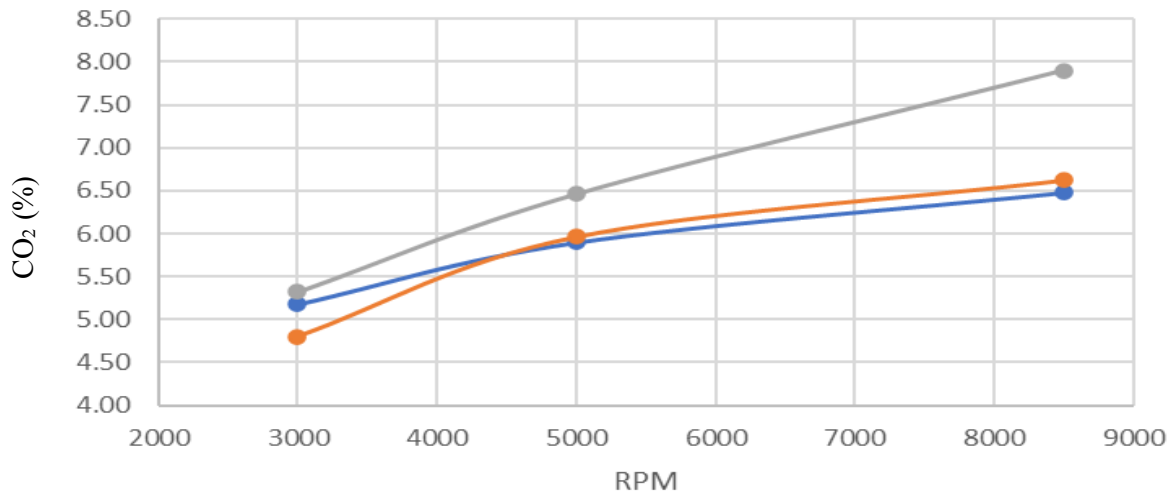


Figure 5. Comparison of exhaust emissions (HC) in fuel mixtures P100, BP10, BP20.

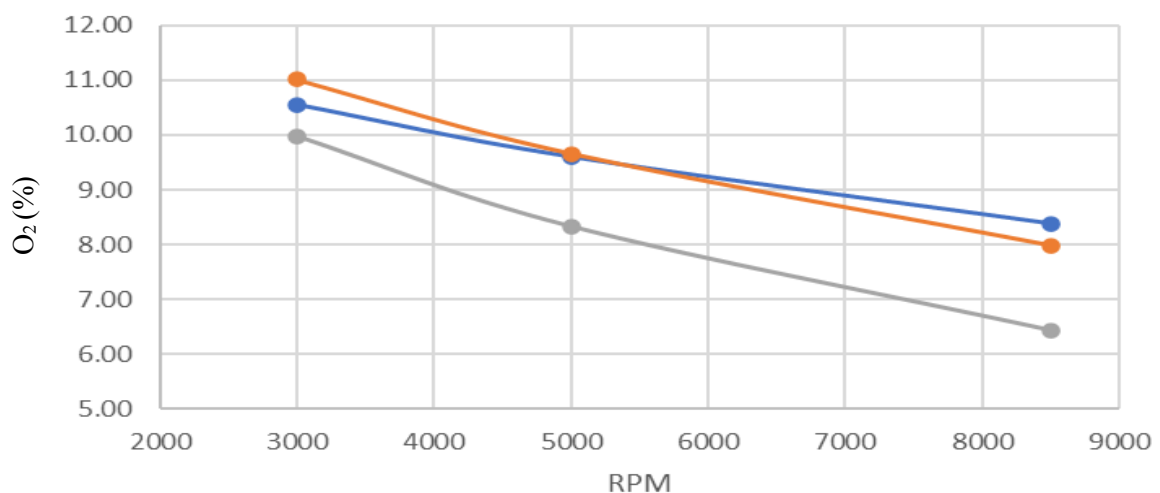
From the test results shown in figure 5, the highest HC is in the P100 mixture of 373 ppm with a rotation of 3000 rpm, while the lowest emission level is in the fuel mixture BP20 = 147 ppm. Starting

from the average exhaust gas emission ratio (HC), compared to the HC government standard of 200-400 ppm, the BP20 fuel output does not meet the standard, but if the HC is reduced, the combustion will be better.



**Figure 6.** Comparison of exhaust emissions (CO<sub>2</sub>) in fuel mixtures P100, BP10, BP20.

From tests carried out using a gas analyzer test tool, the results are shown in figure 6: CO<sub>2</sub> emissions at engine speed of 3,000 rpm with results P100 = 5.18%, BP10 = 4.80%, BP20 = 5.32% and at engine speed 5500 rpm emission level P100 = 5.90%, BP10 = 5.96%, BP20 = 6.46%, and at 8500 rpm the emission level is P100 = 6.48%, BP10 = 6.62%, BP20 = 7.90%. At 3000 rpm, the CO<sub>2</sub> in the BP10 mixture has the lowest levels compared to government standards with levels of 12-15%, so that the BP10 mixture does not meet the standards with a yield of 4.80%. If the CO<sub>2</sub> drops, the scale on the engine block is thick, it is advisable to check the engine.



**Figure 7.** Comparison of exhaust emissions (O<sub>2</sub>) in fuel mixtures P100, BP10, BP20.

The test results are shown in figure 7, the highest O<sub>2</sub> is in the BP10 fuel produced at 3000 rpm engine speed, namely 11.01%, while the lowest O<sub>2</sub> performance is in the BP20 fuel mixture with an emission level of 6.43% at 8500 rpm. Compared to the government standard level of 0.5-2%, the fuel yield of

BP20 has a grade of 6.43% which far exceeds the fuel standard. A high O<sub>2</sub> level indicates a problem with the exhaust that may be leaking / clogging.

#### 4. Conclusion

The effect of using a mixture of plastic fuel oil with Pertamina on engine power and torque performance was investigated. The highest torque was P100 fuel or 11.308 Nm pure plastic oil at a rotation of 4500 rpm. The highest power generated was observed in the mixture of BP20 or 80% Pertamina fuel and 20% plastic oil at 8.24 kw at 8250 rpm. The best exhaust emission for CO = 4.33% at 3000 rpm was with P100 fuel and the highest emission value obtained for gas O<sub>2</sub> = 6.43% at 8500 was with a BP20 fuel mixture. Of the three test results, good fuel was coded P100 (pure plastic oil) but because P100 is difficult to find, another option is to use plastic fuel code BP20.

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