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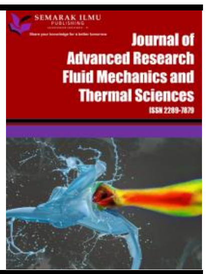

The Effects of Alternative Fuel Mixture of HDPE Plastic and Gasoline on Four-Stroke Engine Exhaust Gas Emissions

Rizqi Fitri Naryanto[1,*], Kriswanto[1], Fahmy Zuhda Bahtiar[2], Mera Kartika Delimayanti[3], Andri Setiyawan[1]

[1] Department of Mechanical Engineering, Universitas Negeri Semarang, Gd E9 Kampus Sekaran Gunungpati, 50229 Semarang, Indonesia
[2] Automotive Technology Vocational Education, Universitas Ivet, Bendan Duwur- Gajahmungkur, Semarang, Indonesia
[3] Department of Computer and Informatics Engineering, Politeknik Negeri Jakarta, 16425, Depok, Indonesia

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ABSTRACT

Alternative fuels, like a mix of pyrolyzed plastic waste and gasoline, have made us less dependent on nonrenewable petroleum. Since HDPE has a low density, it is perfect for producing more oil at temperatures as low as 400^{o}Celsius. It has a density of around 0.94 g/cm^3, whereas gasoline is between 0.60 g/cm^3 and 0.78 g/cm^3. This study compared a blend of C10 and C20 gasoline at engine speeds of 1500, 2000, and 2500 rpm to C0 gasoline. Results indicated that as speed increased, exhaust gas emissions such as HC and CO levels in pure gasoline (C0) dropped, whereas levels in the combination increased. This demonstrates that a mixture of gasoline and HDPE damages the environment.

1. Introduction

Alternative fuels refer to a mixture of pure fuel and other substances in certain ratios. They are used to reduce overreliance on regular fuel. Plastic is an example of a fuel mixer with many advantages compared to other materials. Since plastic wastes are not biodegradable, they cause environmental problems, especially in major cities. Environmental experts and scientists from various disciplines have conducted studies and taken various actions to curb this problem.

Most plastic wastes exist in different classes of polymers, including high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS) and polyethylene terephthalate (PET) [1]. These are high molecular weight organic polymers containing other substances. They are synthetic and commonly derived from petrochemicals [2].

Plastic waste can be used as an alternative fuel mixture. However, this involves several processes, including treating the waste with biodegradable plastic, burning waste, and pyrolysis. These processes break down of material at high temperatures with limited air to create a product in the

* *Corresponding author.*
E-mail address: rizqi_fitri@mail.unnes.ac.id

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form of gas and liquid and a heating pad as solids that remain in the reactor. The product is plastic waste oil as an alternative fuel, and biomass energy [3,4].

Chemically, HDPE (High-Density Polyethylene) plastic has a low density, and producing it yields more oil at a low temperature of 400°C. Furthermore, it has a high density of approximately > 0.94 g/cm^3, equivalent to a gasoline density of 0.60-0.78 g/cm^3. Since the HDPE plastic and gasoline have almost the same characteristics, pyrolysis from HDPE plastic waste can be mixed [5,6].

The use of plastic waste oil needs knowledge in the type of emission produced to ensure that it does not negatively influence human survival. Emission values exceeding the permissible threshold are very harmful to the environment. Hazardous gas emissions from the combustion process are hydrocarbon (HC) and carbon monoxide (CO) gas [7,8]. A part from harming human health, increased vehicle volume, and air pollution influence natural conditions or global warming. Research on emission levels from plastic waste oil has not been widely conducted. This determines HDPE's effect as a mixture with gasoline fuel on the level of exhaust gas emissions. Experiments were performed under conditions C0 (100% pure premium), C10 (a mixture of 90% gasoline and 10% plastic oil), and C20 (a mixture of 80% gasoline and 20% plastic oil) with engine speeds of 1500, 2000 and 2500 rpm, by measuring carbon monoxide (CO) and hydro carbon (HC). Plastic waste was processed by pyrolysis to produce HDPE oil mixed with the gasoline to be used as fuel in research [9,10].

2. Materials and Method

In this research, we had already conducted some steps using the materials on the methods. Plastics were used for executing the process mixed with the gasoline. Most plastic wastes exist in different classes of polymers, including high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), and polyethylene terephthalate (PET).

2.1 Plastic Technology

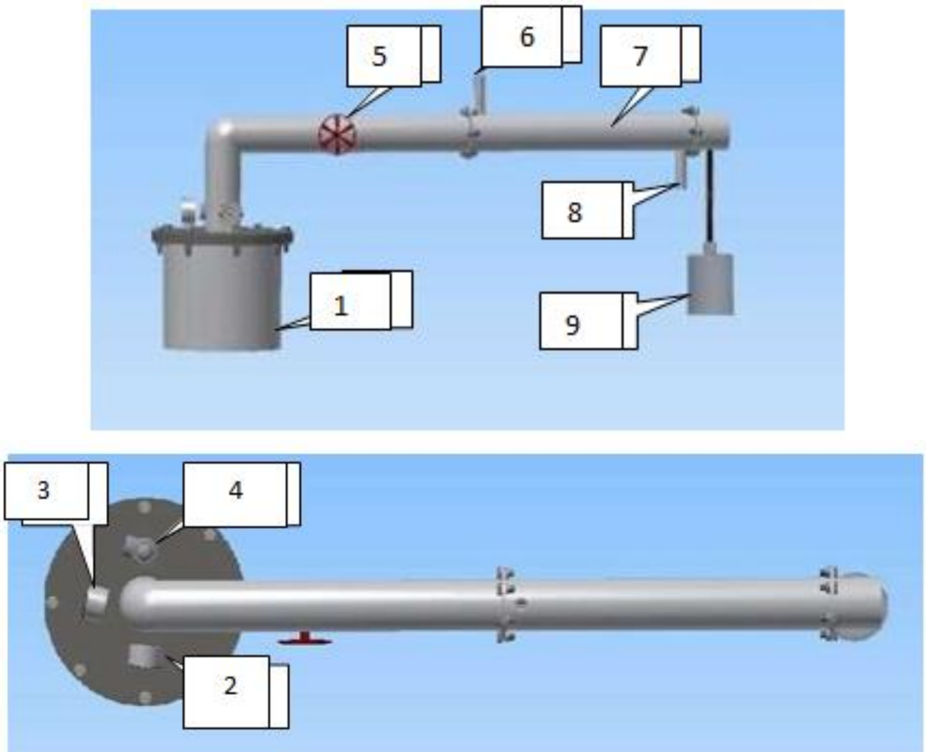
Industrial plastics are more homogeneous and environmentally friendly, making them useful for down-cycling into lower-grade plastic products. Municipal plastics are more heterogeneous, containing foreign substances. Approximately 10.675.1 wt% of Municipal waste contains plastics [11,12]. Its waste mainly includes low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), and poly (vinyl chloride) (PVC). About 50-70% of the total plastic waste is packaging materials from polyethylene, polypropylene, polystyrene, and polyvinyl chloride [9]. Averagely, polyethylene makes up the greatest fraction of all plastic wastes (69%), and it comprises 63% of the total packaging waste [9,11].

Polyethylene (PE, low and high density) and polypropylene (PP) are the most widely used plastics [13]. HDPE is recyclable and can be discovered in plastic bottles, storage boxes, pipes and cable insulations, and many other applications. LDPE can manufacture computer parts, toys, soft bottles, wrappers, back sheets for diapers, and several additional applications. In the packaging industry, all three polymers, PP, PS, and PE, are widely use [5,6]. A copolymer of ethylene and propylene is frequently utilized as a rubber and in computers [5]. Poly (vinyl chloride) (PVC) is another popular plastic suitable in many applications, such as plumbing pipes, electrical cable insulation, tubing, automobile seat covers, and rubber replacement. Poly (ethylene terephthalate) (PET) is a common polymer with many applications, including films, fibers, food containers, and beverage bottles [14].

2.2 Pyrolysis

This is the degradation of a material at high temperatures without oxygen by the thermochemical process. In plastic material, temperature between 300-500°C is required to form a gas condensed and distilled, producing oil and pulp in the form of char [15].

Studies related to fuel production from plastic HDPE and LDPE have been widely conducted. Plastic pyrolysis oil increases the efficiency of 100 cc motors by 15-20% compared to gasoline. The HDPE and LDPE oils have the same densities as gasoline and fuel, respectively. The pyrolysis process at low temperatures requires a catalyst for efficient combustion [16]. The pyrolysis process had been conducted, as illustrated in Figure 1.



1. Pyrolysis reactor
2. Thermometer
3. Manometer
4. Safety valve
5. Faucet valve
6. Cooling water output
7. Condenser
8. Cooling water input
9. Container

Fig. 1. Pyrolysis apparatus of plastic HDPE

2.3 Gasoline Fuels

This is a clear, yellowish distilled fuel oil. The yellow color is due to the presence of additional dye. This fuel is widely used in internal combustion engines (ICE), especially for spark engines. The fuel quality has many effects on the combustion process. Therefore, the power generated is at maximum. A good fuel reduces knocking due to high pressure and temperature in the combustion chamber. These characteristics are called octane numbers in fuel.

The research was conducted using a mixture of plastic waste oil with fuels C0 (100% pure premium), C10 (a mixture of 90% gasoline and 10% plastic oil), and C20 (a mixture of 80% gasoline and 20% plastic oil). It was performed on 125 cc motorcycle vehicles based on the specifications in Table 1, with engine speed variations of 1500, 2000 and 2500 rpm.

Table 1
Engine specification

Variables	Dimension
Engine type	4 stroke SOHC
Diameter x stroke	52.4 mm x 57.9 mm
Cylinder volume	125 cc
Maximum Power	9.3 PS/7500 rpm
Maximum Torque	1.03 kgf.m/400 rpm
Compression comparation	9.0 : 1
Clutch type	Automatic, centrifugal
Lubrication System	Wet
Cooling System	Air Cooling System
Fuel system	Carburetor
Transmission Type	Rotary, 4 speed
Ignition system	DC - CDI
Working Engine temperature	70°C – 80°C.
Engine type	4 stroke SOHC

3. Result and Discussion

This research uses High-Density PolyEthylene (HDPE) plastic oil processed by pyrolysis as a gasoline fuel mixture. This was meant to produce HDPE oil that is mixed with gasoline fuel [17]. The plastic waste oil from the process is tested in a laboratory with the results shown in Table 2.

Table 2
Laboratory test results of HDPE plastic oil

No	Test Type	Unit	Test Result
1	Research Octane Number (RON)		72.1
2	Motor Octane Number (MON)		55.4
3	(RON+MON)/2		63.8
4	Flashpoint	(°C)	36

Based on laboratory test data, HDPE plastic oil has an octane number of 63.8, while gasoline fuel oil has an 88. The plastic oil has a heat value of 45,594 J/g, and a flashpoint of 36°C, while gasoline has a -43°C. The mixing of HDPE and gasoline petrol fuel is performed with the following composition as shown in Figure 2.

Fig. 2. Pure HDPE plastic oil, Pure Premium gasoline, C10 Mixture, C20 Mixture

3.1 C10 Mixture (90% Gasoline and 10% HDPE Plastic Oil)

The mixture of gasoline fuel and HDPE plastic oil is 90% and 10% with a volume of 450 ml gasoline and 50 ml plastic oil, respectively. The laboratory results are shown in Table 3. In the C10 mixture variation, the octane value increased by 85.4 from the HDPE plastic waste oil mixture of 63.8. Flashpoint on this variation is 34°C decreased from the mixture of HDPE plastic waste oil and 36°C gasoline.

Table 3
Laboratory test results of C10 fuel (90% gasoline and 10% plastic waste oil)

No	Test Type	Unit	Test Result
1	Research Octane Number (RON)		89.1
2	Motor Octane Number (MON)		81.7
3	(RON+MON)/2		85.4
4	Flashpoint	(ºC)	34

3.2 C20 Mixture (80% Gasoline and 20% HDPE Plastic Oil)

A mixture of gasoline fuel and HDPE plastic oil is a percentage of 80% and 20%, respectively, with a volume of 400 ml gasoline and 100 ml plastic oil. The laboratory results are shown in Table 4.

Table 4
Laboratory test results of C20 fuel (80% gasoline and 20% HDPE plastic oil)

No	Test Type	Unit	Test Result
1	Research Octane Number (RON)		83.5
2	Motor Octane Number (MON)		89.5
3	(RON+MON)/2		86.5
4	Flashpoint	(°C)	35.5

According to Figure 3 and Table 5, in pure gasoline premium type (C0), the exhaust gas emission level decreases according to the engine speed. However, it is different from the fuel mixtures (C10, C20), which undergo an increase in CO levels at an engine speed of 1500-2500 rpm.

More details can be seen in the graph below.

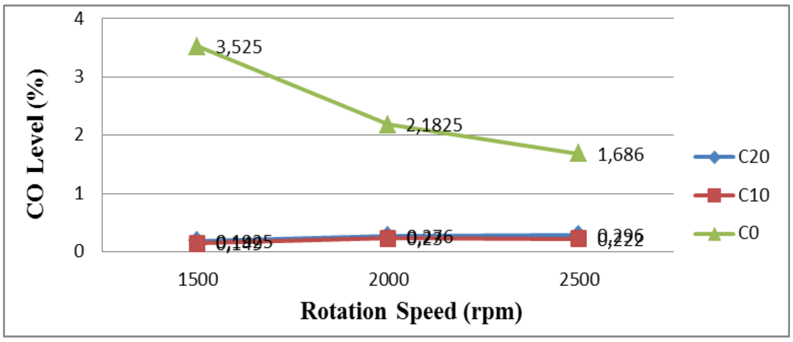


Fig. 3. A graph illustrating the CO gas emission levels on the variations in C0, C10, C20 fuel mixtures

Table 5
CO Exhaust Gas Emissions from C0, C10, C20 fuel mixtures

Speed (Rpm)	Trial	CO levels (%)		
		Pure Gasoline (Premium)	A Mixture of Pure Gasoline (Premium)	
		C0	C10	C20
1500	1	3.914	0.175	0.193
	2	3.136	0.123	0.192
	Average	3.525	0.149	0.1925
2000	1	2.162	0.277	0.286
	2	2.203	0.183	0.266
	Average	2.1825	0.23	0.276
2500	1	1.699	0.232	0.273
	2	1.673	0.212	0.319
	Average	1.686	0.222	0.296

Figure 4 and Table 6 shown that in all variations of the fuel mixture (C0, C10, C20), the level of HC exhaust gas emissions decreases based on the engine speed. An increase in engine speed reduces the level of HC gas emissions at a stationary rotation [18,19]. In this case, the engine rotation speed is 1500-2500 rpm. More details can be seen in the graph below.

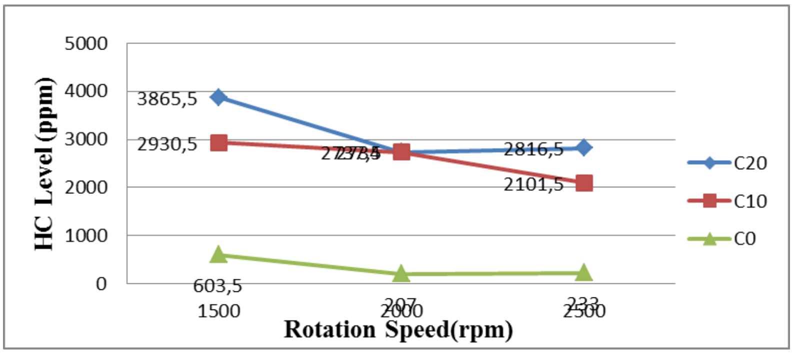


Fig. 4. A graph illustrating the HC gas emission levels on the variations in C_0, C_{10}, C_{20} fuel mixtures

Table 6
The results of HC exhaust gas emissions from C0, C10, C20 fuel mixtures

Speed (Rpm)	Trial	HC levels (ppm)		
		Pure Gasoline (Premium)	A mixture of gasoline and HDPE plastic oils	
		C0	C10	C20
1500	1	700	2864	3766
	2	507	2997	3965
	Average	603.5	2930.5	3865.5
2000	1	171	2558	3244
	2	243	2910	2231
	Average	207	2734	2737.5
2500	1	259	2239	3569
	2	207	1964	2064
	Average	233	2101.5	2816.5

According to Table 7, there are differences in the octane numbers in HDPE plastic oils and mixtures C10 and C20. The higher the percentage of used plastic oil, the lower of the octane number. The low octane value has an impact on knocking. A collision between an explosion of fuel mixture (before a flame) and the fuel ignited by the spark plug, causing a sound, is known as knocking. Furthermore, there is a flashpoint variable. This is the lowest temperature at which the oil vapor or fuel in the mixture with the air ignites when subjected to a flame test (ignition) under certain conditions. The high flashpoint on fuel affects the resistance to ignition. The higher of the proportion from used plastic oil, the higher of the flashpoint.

Table 7
Analysis of plastic waste oil characteristics and mixture variations

No	Variations	Octane Number (RON)	Flashpoint (°C)
1	HDPE Plastic Waste Oil	72.1	36
2	C_{10}	89.1	34
3	C_{20}	83.5	35.5

Based on the results of exhaust gas emissions in Table 8, the highest levels of exhaust emissions in a row are in the specimen with a mixture of 20% plastic waste oil compared to a mixture of other percentages. For 20% fuel, exhaust gas emissions are lowest compared to 10% pure or unmixed fuel. This is due to detonation where the fuel burns without any ignition. It is caused by high temperature in the space, exceeding the flashpoint and the fuel crust sticking to the cylinder wall. The attached crusts burn during the work cycle of the vehicle, causing the knocking.

Table 8
Analysis of HC and CO exhaust emission levels

No	Variations	1500 rpm		2000 rpm		2500 rpm	
		HC (ppm)	CO (%)	HC (ppm)	CO (%)	HC (ppm)	CO (%)
1	C0	603.5	3.525	207	2.1825	233	1.686
2	C10	2930.5	0.149	2734	0.23	2101.5	0.222
3	C20	3865.5	0.1925	2737.5	0.276	2816.5	0.296

The high heat generated in the fuel after combustion increases the combustion chamber temperature. Furthermore, this affects the temperature of the air entering the cylinder. The higher of the air temperature, the denser of the molecules. The air molecules density increases the amount of air drawn by the piston into the combustion chamber, making the mixture to become lean condition. This reduces HC gas emission levels. A lean condition causes the length of fire to burn the fuel mixture with air, increasing the combustion rate than the piston speed. However, it does not apply to CO in fuel mixture with plastic oil.

At an engine speed of 1500 rpm, the HC gas emission in each research has the highest level than 2000 and 2500 rpm. This is because the throttle valve is fully closed, and therefore the air entering the combustion chamber due to piston suction is less than the fuel.

4. Conclusions

This research involved producing gasoline of C0, C10, and C20 fuel mixes with engine speed variations of 1500, 2000, and 2500 rpm. The results show a decrease in the HC and CO exhaust gas emission levels at pure gasoline (C0), with an increase in the engine speed. Also, the HDPE mixture (C10, C20) experienced a decrease in HC levels and an increase in CO in the engine speed. This shows that HDPE mixed fuel is environmentally less friendly compared to pure premium.

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