The effect of gasoline-waste plastics oil blends on SI engine performance at high-speed rotation

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Abstract. As well known that waste plastic could be considered a very serious environmental issue because of their disposal problems may affect human life. One of the solutions to solve the plastic waste problem is to convert the plastic waste become plastic oil. This research was aimed to study the effect of gasoline-waste plastics oil (WPO) blends on (SI) engine performance at high-speed rotation. In this experiment, the engine of Honda GP 160 H-SD was selected which has specification a single-cylinder spark ignition, power is 5.5 HP and output net 3600 rpm. The composition of gasoline-waste plastic oil blends was variated of about WPO-10, WPO-20 and WPO-30. WPO-10 means that the waste plastic oil was added in gasoline oil of about 10 % vol. The SI engine performance was elucidated such as engine power, specific fuel consumption and thermal efficiency. The experimental results show that increasing speed rotation from 1500 to 3000 rpm greatly increases engine output power and specific fuel consumption. Consequently, the thermal efficiency reduced by 21.1%. It is also found, the increasing of blending ratio to WPO-30 has dropped the SI engine power approximately by 10.3 %. As results the specific fuel consumption reduced by 17.4 % while thermal efficiency can be increased by 15.5 %.

Keywords: Waste plastic oil (WPO), Engine performance, Renewable fuel.

1. Introduction
Nowadays, the fossil fuel have been used huge every sector that using machine. In otherside, the fossil fuel will be run out in under 30 years. Therefore, many researchers have sought the solutions for substitute fuels that are compatible with fossil fuels. According to Surono & Ismanto[1], the needs of plastic were increasing year to year so that increased plastic production average of 200 tons per year in Indonesia [1-3]. On other side, plastic has more advantages than other material however plastic waste also has negative impact on the environment because plastic waste can't decompose in nature and can reduce soil fertility. Plastic waste can clog drainage channels, gutters and rivers so that can cause flooding. Burning plastic waste can harmful to human health because the air was polluted. The alternative way to handle plastic waste that is currently being researched and developed is to convert plastic waste into plastic oil. The accumulation of plastic waste problems on earth can be overcome with plastic waste use as feedstock for fuel, beside plastic waste is a cheap feedstock and easy to find. Previous researcher have been conducted by Nurdianto et al.[4] is to determine the exhaust
emissions content from gasoline-waste plastic oil (WPO) blends with variation blends. The result obtained that the waste plastic oil-gasoline blends is feasible to use in accordance with Indonesian national standards (SNI) and constitution decision of the Minister of Environment No. 05 Year 2006 [4]. This work attempts to expand the knowledge on possibility waste feedstock for renewable fuel. It is important to addressed, the waste plastic oil-gasoline blends has not been elucidated in depth on engine power, specific fuel consumption and thermal efficiency in previous study as renewable fuel for internal combustion engines. Therefore, the objective of this study is to examine the suitable of gasoline-waste plastic oil blend fuel on SI engine as a potential fuel source of future energy supply. Especially to find out the effect of waste plastic oil-gasoline blends on the performance of gasoline engines with several variations of waste plastic oil: gasoline, 10:90 called WPO-10, WPO-20, WPO-30 compared to pure gasoline on SI engine.

2. Experimental Procedures
The engine test was operated under speed of varies from 1500 to 3000 rpm with 500 rpm interval range for each type of fuel. A tachometer used to determine the engine rotation, volt meter was used to determine voltage and clamp meter was used to measured electric current of engine load. Figure 1 shows the experimental setup of the engine [5]. The experiment was repeated for three times and the mean value was calculated for each sample. The experiment was conducted in Engine Laboratory, Department of Mechanical Engineering, Faculty of Engineering, Syiah Kuala University. The testing on Honda GP 160 H-SD engine which has specification a single-cylinder spark ignition, power is 5.5 HP and output net 3600 rpm in order to determine performance of engine such as power, specific fuel consumption and thermal efficiency by using gasoline-waste plastic oil as a fuel with several blends variation (WPO-10, WPO-20, WPO-30) compared to pure gasoline fuel.

![Figure 1. Schematic diagram of experimental setup.](image)

3. Result and discussion
3.1. The characteristic physical properties of waste plastic oil
In this study, the characteristic properties of waste plastic oil are analyzed and shown in Table 1. From the results shown that the characteristics of plastic oil that are in accordance with gasoline fuels that have been set and used by the Indonesia government based on national standard as a comparison to WPO. There are some characteristics in accordance with the national standard include viscosity, density, sulfur content and calorific value. Table 1 shows the kinematic viscosity of WPO is 3.5 mm$^2$/s, which as higher than reported by Ananthakumar et al. obtained kinematic viscosity of WPO 2.52 mm$^2$/s [6]. The density of WPO is 750 Kg/m$^3$ this slightly lower than gasoline density but still acceptable. The sulphur content of WPO was obtained 0.68 % mm. The calorific value was obtained for WPO 45.0196 MJ/kg and this value is higher than waste plastic oil which is 42.8075 MJ/kg was
recorded by Kumar et al. [7]. Zainur also reported that calorific value from plastic waste oil was obtained 46.848 MJ/kg [8].

Table 1. The physical properties of waste plastic oil

| No | Properties          | Unit       | ASTM D6751 | Gasoline range | WPO-a | WPO-b[^1] | Method       |
|----|---------------------|------------|------------|----------------|-------|-----------|--------------|
| 1  | Kinematic Viscosity | (mm²/s)    | 1.9–6.0    | 2.0 - 5.0      | 3.5   | 2.64      | ASTM D4052   |
| 2  | Density             | (Kg/m³)    | 880 max.   | 815 - 870      | 750   | 830       | ASTM D445    |
| 3  | Sulphur Content     | % mm       | Max. 0.05  | 0 – 3.5        | 0.68  | -         | ASTM D664    |
| 4  | Calorific Value     | MJ/kg      | -          | -              | 45.0196 | 42.8075  | ASTM D240    |

[^1] Value measured, ^[1]Vijaya Kumar.

3.2. Engine performance test

The gasoline engine performance test included measurement or calculation of engine power (P), calculation of specific fuel consumption (SFC) and also calculation of efficiency ($\eta_{th}$).

3.2.1. Engine Power:

According to Priambodo and Maleev [9], the power generated by an engine connected to a single-phase a-c generator can be calculated by the equation:

$$N_b = \frac{E.I pf}{746 eg}$$  \hspace{1cm} (1)

Where:
- $N_b$ = Engine Power (HP)
- $E$ = Voltmeter Reader (Volt)
- $I$ = Ampermeter Reader (Ampere)
- $Pf$ = Power factor for one single phase = 1
- $E_g$ = Efficiency of electric generators for engines under 50 kVA = 87% - 89%.

For generators using V belts, the power generated is divided by $\eta_b = 0.96$.

The engine power produced for waste plastic oil - gasoline blends and compare to pure gasoline are shown in Figure 2. The pure gasoline fuel give the highest engine power which is 1.339 kW, while the waste plastic oil - gasoline blends obtained 1.287 kW, 1.244 kW and 1.229 kW for WPO-10, WPO-20 and WPO-30, respectively. WPO-30 obtained as the lowest engine power at 1500 rpm. The highest power produced at 2000 rpm and 2500 rpm engine speed was obtained 1.72 kW and 2.002 kW using gasoline fuel, respectively. Beside, the lowest power shown that 1.381 kW and 1.721 kW using WPO-30. The gasoline fuel obtained 2.219 kW at 3000 rpm engine speed, while the waste plastic oil - gasoline blends obtained WPO-10 (2.19 kW), WPO-20 (2.05 kW) and WPO-30 (1.99 kW). The WPO-30 blends give the lowest result of engine power, but WPO-10 at each engine speed shows that are not too significant different from pure gasoline result.
Figure 2. The engine power (kW) for WPO-10, WPO-20, WPO-30 and compare to pure gasoline.

3.2.2. Specific Fuel Consumption.
The specific fuel consumption (sfc) is defined as the amount of fuel that consumed by the engine to produce power in kW/h. This specific fuel consumption measured of fuel consumption by an engine, which is usually measured in mass of fuel from output power. According to Marthur [10], the specific fuel consumption can be calculated by the equation below:

\[ \text{sfc} = \frac{m_f}{N_b} \]  \hspace{1cm} (2)

Where:  
- sfc = Specific fuel consumption (kg/kWh)  
- mf = Total fuel consumption (kg/hour)  
- Nb = Engine power (kW)

The specific fuel consumption of gasoline - plastic waste oil blends WPO-10, WPO-20 and WPO-30 are shown in Figure 3 and compare to pure gasoline fuel. Based on the Figure 3, specific fuel consumption of gasoline fuel was the highest compared to WPO-10, WPO-20 and WPO-30. The sfc of gasoline at 1500 rpm was obtained 0.351 kg/kWh compared to WPO-10, WPO-20 and WPO-30 which is 0.3496 kg/kWh, 0.3295 kg/kWh, and 0.3254 kg/kWh, respectively. This may caused by the absence of excessive impurities contained in gasoline so that combustion in the engine doesn’t experienced problems, and due to the higher calorific value of gasoline compared to WPO. Generally, the result shown that the value of sfc from gasoline-waste plastic oil blends still in line with fuel standard, this can be a reference for further development in future research.
Figure 3. The specific fuel consumption for WPO-10, WPO-20, WPO-30 and compare to pure gasoline.

3.2.3. Thermal Efficiency
Thermal efficiency is defined as the utilization efficiency of heat from fuel to be converted into mechanical work. According to Mathur [10], the thermal efficiency ($\eta$) can be calculated using the equation:

$$\eta = \frac{N_b \times 632.5}{m_f \times LHV}$$

(3)

Where:
- $\eta$ = thermal efficiency (%) 
- $N_b$ = Engine Power (kW) 
- $m_f$ = Fuel Consumption (kg/hour) 
- LHV = Fuel Calorific Value (kcal/kg).

Thermal efficiency is the ratio between work output and the heat available introduced through fuel injection. The variation of thermal efficiencies using gasoline - waste plastic oil fuel blends and gasoline fuel is showing in Figure 4. It can be seen that the thermal efficiency for WPO-10, WPO-20, WPO-30 were 16.09%, 17.08%, and 17.3% compared to gasoline fuel which is about 16.02%, respectively. Based on the result from experiments conducted, it can be concluded that the higher engine speed will decreased the thermal efficiency from all type of fuel. This due to combustion process faster at higher engine speed and required more fuel than at lower engine speed. This has an effect on thermal efficiency WPO-10 due to time needed to burn in the engine is longer than the gasoline, WPO-10 and WPO-20.
4. Conclusion
The present result found that degummed process has improved the waste plastic oil properties. The experimental results proved that waste plastic oil blends is a potential alternative fuel which can be used directly in SI engine without any modification. When engine operated under high speed of about 3000 rpm and fueled of the WPO-10 shown that the engine performance (2.19 kW) approaching gasoline fuel result (2.219 kW). Furthermore, the experimental results show that increasing engine speed from 1500 to 3000 rpm greatly increases the specific fuel consumption for WPO-10, WPO-20 and WPO-30 which was 0.4566 kg/kWh, 0.429 kg/kWh, 0.402 kg/kWh and increases engine output power, respectively. On the other hand, the increasing speed rotation from 1500 to 3000 rpm greatly consequently, the thermal efficiency reduced by 21.1%. It is also found, the increasing of blending ratio to WPO-30 has dropped the SI engine power approximately by 10.3 %. As results the specific fuel consumption reduced by 17.4 % while thermal efficiency can be increased by 15.5 %.

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