Influences of Fuel Additive, Crude Palm and Waste Cooking Oil on Emission Characteristics of Small Diesel Engine

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Abstract. Major research has been conducted on the use of input products, such as rapeseed, canola, soybean, sunflower oil, waste cooking oil (WCO), crude palm oil (CPO) and crude jatropha oil as alternative fuels. Biodiesel is renewable, biodegradable and oxygenated, where it can be easily adopted by current existing conventional diesel engine without any major modification of the engine. To meet the future performance and emission regulations, is urged to improve the performance and exhaust emissions from biodiesel fuels. Hence, further investigation have been carried out on the emission characteristics of small diesel engine that fuelled by variant blending ratio of WCO and CPO with booster additive. For each of the biodiesel blends ratio from 5 to 15 percent volume which are WCO5, WCO10 and WCO15 for WCO biodiesel and CPO5, CPO10 and CPO15 for CPO biodiesel. The exhaust emissions were measured at engine speeds varied at 2000 rpm and 2500 rpm with different booster additive volume DRA (biodiesel without additive), DRB (0.2 ml) and DRC (0.4 ml). Emissions characteristics that had been measured were Hydrocarbon (HC), Carbon Monoxide (CO), Carbon Dioxide (CO₂), Nitrogen Oxide (NOₓ), and smoke opacity. The results showed that increased of blending ratio with booster additive volume significantly decreased the CO emission, while increased in NOₓ and CO₂ due to changes of fuel characteristics in biodiesel fuel blends.

1.0 Introduction

Biodiesel has been shown to produce lower tailpipe emissions than regular fuel. Biodiesel is considered biodegradable, an oxygenated and renewable even if spilled it is still considered to be much less harmful to the environment or called as environmentally friendly bio-fuel [1-2]. The best thing about biodiesel is a fatty acid alkyl ester which are renewable resources, biodegradable and non-toxic fuel which can be derived from any vegetable oil by transesterification process [3-7]. Nowadays the increase of human population around the world that mean more people, vehicle and electrical has...
tremendously increased in our daily energy demand of oil resources. High demand of oil resources has resulted wide spread exploitation of the petroleum reserves, which are getting depleted at a high-speed and high impacted of environmental pollution of increasing exhaust emission, so there is a need to search for other alternatives fuels [3][8-11]. Moreover, the combustion of using diesel has polluted the environment [12]. Biodiesel can be adopted as an alternative fuel for existing conventional diesel engines as the blended form of waste vegetable oil and diesel, the most important is that without require any major modifications of the mechanical system of the engines.

Biodiesel emissions in conventional diesel engine contain substantially less unburned carbon monoxide (CO), sulfur, polycyclic aromatic hydrocarbons, hydrocarbon (HC), nitrated polycyclic aromatic hydrocarbons and particulate matter (PM) than conventional diesel emissions. Many types of fuel additives found shows positive result in term of increasing the engine performance, fuel properties such as cetane number, combustion and most important decrease engine emissions. Those characteristics of the fuel can reduce the engine emissions such as carbon monoxide (CO), hydrocarbon (HC), and particulate matter (PM) in the exhaust [14-18]. Hence, many of emissions studies were carry on by using different types of biodiesel which are blended with different ratio of fuel additive. This research investigate the effect of percentage of fuel additive in biodiesel fuels at different speed of engine on the exhaust emissions.

2.0 Methodology and Experimental Setup
The fuels tested were an ordinary diesel (OD) and blends of 5 vol% (WCO5), 10 vol% (WCO10) and 15 vol% (WCO15) waste cooking oil. Then, each of blended biodiesels were blend again with different ratio of fuel additive. Under booster additive condition, the blending ratio for 10 litres of biodiesel will be added with DRB (0.2 ml) and DRC (0.4 ml) of booster additive ratio for all conditions and compare with biodiesel without additive DRA (Base). Table 1 shows the results of the test fuel that obtained through the fuel properties test with the aid of listed apparatus in Thermodynamic Laboratory of University Tun Hussein Onn Malaysia. In this research, the kinematic viscosity of the waste cooking oil blend was measured by a Viscolite 700 model VL700-T15. The density was measured using a Metter Toledo diamond scale model JB703-C/AF. The water content in the biodiesel sample was measured using a Karl Ficher Tirator Water Content Analyser V20. The flash point was measured using a Pensky-Martens PMA 4.

| FUEL TYPE | Density (g/cm³) | Kinematic Viscosity (Cp) | Flash Point (°C) | Water Content (%) | Acid Value (mg KOH/g) |
|-----------|-----------------|--------------------------|-----------------|------------------|----------------------|
| OD        | 0.8340          | 3.0                      | 83.0            | 0.0079           | 0.423                |
| WCO5DRA   | 0.8385          | 3.7                      | 83.0            | 0.012            | 0.6122               |
| WCO5DRB   | 0.8365          | 3.6                      | 83.0            | 0.011            | 0.6403               |
| WCO5DRC   | 0.8370          | 3.7                      | 83.0            | 0.014            | 0.6403               |
| WCO10DRA  | 0.8488          | 3.9                      | 85.5            | 0.015            | 0.7203               |
| WCO10DRB  | 0.8440          | 3.9                      | 86.5            | 0.016            | 0.7283               |
| WCO10DRC  | 0.8445          | 3.8                      | 85.0            | 0.015            | 0.7260               |
| WCO15DRA  | 0.8622          | 4.4                      | 89.0            | 0.019            | 0.9174               |
| WCO15DRB  | 0.8598          | 4.4                      | 89.0            | 0.018            | 0.9154               |
| WCO15DRC  | 0.8601          | 4.3                      | 88.0            | 0.018            | 0.9176               |
Figure 1 shows the schematic diagram of biodiesel blending process. The WCO blended with biodiesel with the listed blending ratio 5-15 vol% (WCO5-WCO15). During the blending process, the blending machine was set to operate at the temperature of 70°C where the machine will auto cut in or cut off to maintain the temperature and the speed of rotating blade is set at the speed of 270 rpm. Each fuel blends will be conducted for 1 hour.

![Figure 1: Schematic Diagram of Blending Process](image1)

![Figure 2: Sample of D20 Booster](image2)

Table 2: Engine specifications

| Engine Specification | HATZ Diesel Engine 1B30 |
|----------------------|--------------------------|
| Model                | Air-cooled four stroke diesel engine |
| Type                 | Direct injection |
| Number of cylinder   | 1 |
| Bore/Stroke          | 80/69 mm |
| Displacement         | 347 cm³ |
| Sense of rotation on power take-off side | left |
| Engine oil pressure at oil temperature of 100°C | 2.5 bar at 3000 rpm |
| Maximum torque       | 17.5Nm |
| Weight               | 40 kg |

Figure 2 shows the sample of D20 booster while Figure 3 shows the schematic diagram of experiment setup respectively that use for the study. The engine that used in the experiments is HATZ Diesel Engine 1B30, small diesel engine with 1 cylinder. Diesel engine 1B30 was design with compact installation dimension and applications with power requirement up to 8 kW due to light weight (40 kg). The maximum torque of the engine is 17.5 Nm, where it use direct injection system and 2.5 bar at 3000 rpm when engine oil pressure at oil temperature of 100°C. The speed of engine was set at 3 different speed which were 1500 rpm, 2000 rpm and 2500 rpm respectively. The engine specification, including the operating parameters with fuel injection, is summarized in Table 2.

![Figure 3: Schematic Diagram of Experiment Setup](image3)
Exhaust emissions, such as Carbon Monoxide (CO), Carbon Dioxide (CO₂), Oxygen (O₂), Hydro Carbon (HC) and Nitrogen Oxides (NOₓ) were measured using Autocheck 5 Channel Gas and Smoke Emission Analyzer. During operation, sampling probes of the gas analyzer comprising a smoke meter and a gas analyzer were mounted centrally at the end of the engine’s exhaust pipe.

3.0 Results and Discussion

The effect of fuel additive blended with waste cooking biodiesel on exhaust emissions was investigated for the ordinary diesel (STD), 5 vol% (WCO5), 10 vol% (WCO 10) and 15 vol% (WCO 15) at engine speeds of 1500, 2000, 2500 and 3000 rpm. The experiments was conducted for 3 hour for each fuels blend and the results of the emission was recorded every hour.

The emissions were observed under different load conditions of 0% and 50% load for all engine operations. Figure 3 shows the relation between the emissions and the engine speed under different blending ratios. As the blending ratio increased up to 15 vol% for all engine speeds, the exhaust emissions mentioned decreased modestly.

Figure 4 illustrated the effect of booster blending with the fuel on emission characteristics. It seems that by increase the booster blending ratio of WCO it shows slightly decrease of the fuel flow rate while in CPO blends it show that the fuel flow rate increasing along the booster blending ratio. For WCO biodiesel fuel blends, the O₂ emission were significantly increasing as the booster blending volume increased compared to CPO biodiesel blends. This phenomena occur meaning that the booster additive react better in WCO compared with CPO where it provide better fuel and air mixing thus increased the O₂ content of the fuel. Due to the fact that biodiesel are oxygenated fuels in others words higher O₂ content and cetane number in biodiesel were lead to higher combustion efficiency and better combustion (high peak temperature), thus decrease the amount of smoke opacity and NOₓ emission. NOₓ formation were high for both WCO and CPO fuel blends because O₂ content of biodiesel is an important parameter in high NOₓ formation because it causing high local peak temperature during combustion process, which will lead to the increase of NOₓ formation.

Figure 5 shows the relation between the emission and the period time of experiment on different biodiesel blending ratio and booster additive volume for CPO and WCO at the speed of engine 2000 rpm. Figure 5 for speed of engine at 2500 rpm. From the figure, it shows the fuel flow rate for both CPO and WCO fuel blends were increased with the increasing of biodiesel blending ratio. As shown in the graph of engine speed at 2500 rpm that WCO hit the highest fuel flow rate which is 5.08 kg/h while the highest fuel flow rate for CPO is 5.36 kg/h. This is due to high density, viscosity and lower heating value of biodiesel blends. Overall the graph shows that the fuel flow rate for WCO is much lower than the CPO, this may due to the higher density and kinematic viscosity of WCO compared to CPO. In the comparison of CO emission between CPO and WCO blends, from the graph it shows significant decrease of CO with the increasing of biodiesel blending ratio in WCO blends compared to CPO due to the increase of biodiesel blending ratio it also increase the O₂ content of the fuel blend as biodiesel O₂ content in its structure which lead to better and more complete combustion process. Thus smaller or lesser O₂ is need for the combustion, main reason for CO and HC emission reduction. But there are also opposite trend was reported by Y.Di and et. al that due to higher WCO biodiesel blending ratio caused higher viscosity of fuel blends which will predominates the fuel atomization and affect the fuel air mixing which will result poorer combustion process and incomplete combustion process [18]. As mentioned earlier, with the higher biodiesel blending mean there are more O₂ content in the fuel blend which will produce better and more complete combustion. Hence more CO transformed into the form of CO₂. This is the reason why WCO blends has higher CO₂ compared to CPO which also mean WCO blends are much cleaner than CPO blends. With better and more complete combustion mean higher thermal efficiency, indirectly increase the NOₓ and HC emission because both of them highly affected by the temperature.
Figure 4 : Effect of booster additive on emission characteristics for WCO and CPO at engine speed 2000 rpm
Figure 5: Comparison of WCO and CPO emission characteristics at engine speed 2500 rpm with different biodiesel blending
4.0 Conclusion
The exhaust emission characteristic of CPO and different blending ratio of WCO biodiesel blends (WCO5, WCO10, WCO15) and with the added of booster additive (0.2 ml 0.4 ml) that performed on small diesel engine with the speed of 1500 rpm, 2000 rpm and 2500 rpm. The results of the study can be summarized as follows:

1. The increase in the WCO and CPO biodiesel blending with the booster additive promotes a reduction in HC and CO emissions due to more oxygen being present during combustion; thus, combustion will become more complete in oxygenated fuel. CPO15 has the lowest CO emissions for all speed conditions.

2. WCO biodiesel fuel blends, the O_2 emission was increased as the booster blending volume increased compare to CPO biodiesel blends due to booster additive react better in WCO compared with CPO where it provide better fuel and air mixing thus increased the O_2 content of the fuel.

3. The increasing of biodiesel blending ratio, both of WCO blends and CPO blends the fuel flow rate was found to be increased as well. This is due to the high density, viscosity and lower heating value of biodiesel.

4. By increasing the booster additive blending ratio of CPO blends and WCO blends, there are slightly decrease of the fuel flow rate for WCO blends while the fuel flow rate increased for CPO blends. By increasing the biodiesel blending ratio along with booster additive ratio is found to increase the Nox emission. This phenomena can be concluded that due to the high contents of O_2 in higher blending ratio and the influences booster additive.

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