Experimental Investigation of Diesel Engine Run with Waste Cooking Oil−Petrol Blends

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ABSTRACT

This paper presents the utilization of the waste cooking oil (WCO) as fuel for diesel engine or also known as compression ignition (CI) engine. The WCO is an alternative biofuel to provide the receding supply of world crude oil as well as recycling the waste. The physiochemical properties of WCO are considered lower than conventional diesel fuel as its density is higher and volatility is lower. Thus the WCO is less prone to evaporate, diffuse and combust during the combustion process. As the matter of fact, the WCO cannot be used as it is because it will create clogging problem at the fuel filter and injector. Therefore, this project has mixes the WCO with conventional petrol fuel (RON95) which is lower density and higher volatility than WCO. The mixing ratio of the WCO and the RON95 was set in the range of 5 to 25 percent of volume based. Initially, the mixing fuel properties such as density and calorific value were investigated. Then, the mixes fuels were tested on the engine performance and the results are compared with the baseline diesel fuel. Based on the results found in this project, lower percentage of WCO (25% of RON95 and 75% of WCO) is suitable to be used for lower engine speed while higher percentage of WCO (5% of RON95 and 95% of WCO) produces a better result at higher engine speed. Nevertheless, the results of all fuel blends are poorer than the conventional diesel fuel. Hence, this project recommends further investigation to be made before WCO can fully utilise although it has potential to be used as fuel in diesel engine.

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Introduction

The demand of world petroleum product has increased significantly because the increasing of industrialization and motorization sectors. Petroleum based fuels are obtained from limited reserves and non-renewable resources; hence, it is necessary to look for renewable alternative fuels [1, 2]. Currently, they are many alternative fuels available in the form of alcohol and vegetable oils [3, 4]. Unmodified waste cooking oil (WCO) is one of promising candidate as an alternative diesel-fuel [5]. Moreover, it can promote waste recycling and preventing illegal dump into the drains that cause ecological pollutants.

However the physiochemical property of WCO is currently considered as poorer than conventional diesel-fuel especially its density and viscosity which are much higher than the diesel-fuel [6-8]. This condition would make WCO less prone to evaporate, diffuse and combust during fuel injection and combustion periods which leads to the reduction in engine performance characteristics as compare to the one run with diesel-fuel [9]. Moreover, some researchers reported that the fuel injector was clogged when run with WCO due to higher viscosity of the WCO [10]. Based on these problems, most of researchers ran diesel engine using modified WCO by either converting it to biodiesel or blend with other volatile fuels.

Among other volatile fuels, this project sees petrol-fuels that has being used for petrol-engine could be blended with WCO since their physiochemical properties are similar and its viscosity is much lower i.e. approximately 1.45 m^2/s [11] as compared to 4.3 m^2/s for diesel-fuel [12]. Also, this project considers the fact of petrol fuel is readily available and upon successfulness of this project that it can be used directly by everybody. Therefore, this project runs diesel-engine with WCO-petrol (RON95) blend fuel.

In order to investigate the diesel-engine performance characteristics when ran with WCO-petrol blend, five fuel blend samples between WCO and petrol-fuel were prepared ranging from 5 to 25 percent volume based of petrol fuel to WCO. The density and calorific value of each sample were measured for reference. The single cylinder test engine (diesel) were first run with diesel-fuel for base line data before each of the fuel sample were tested one by one on the similar engine. The engine performance characteristics for each run were recorded and analysed. The details of the experimental method and results are described in the following sections.

Methodology

The methodology of this project can be divided into two parts. The first part is fuel preparation and the second part is performance testing.

For the fuel preparation, the WCO were collected from local restaurant and the petrol (RON95) and the diesel were brought from local petrol station. Note that the WCO is from uncontrolled product used for frying process. Upon receiving the WCO, it was filtered by using nylon mesh filter to dispose of waste materials during cooking. The WCO is then blended with petrol for 5, 10, 15, 20 and 25 percent volume based of RON95 and named as R05W95, R10W90, R15W85, R20W80 and R25W75, respectively. In order to ensure the fuel blends of WCO-petrol were mixes properly, they were then stirred using hot-plate stirring machine. After that, the weight of 140 mL of each WCO, WCO-petrol blends, petrol and diesel were measured using weight analytical balance machine and the density of the WCO were calculated, respectively. Furthermore, their calorific values were also measured using bomb calorimeter, respectively.

As for the performance test, a single-cylinder, 230 cc, four-stroke, diesel engine made by Robin model DY23 with maximum output of 4.8 kW were used. The engine was coupled with electric engine dynamometer. The schematic diagram of the engine set-up is illustrated in Figure 1. Based on the diagram, the fuel supply system were modified as dual tank, diesel and fuels blend, respectively controlled by a valve. This setting will allow the switch between diesel during starting and stopping the engine and fuels blend during testing.

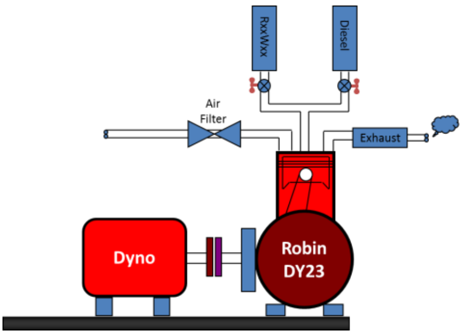

Figure 1: Schematic diagram of engine set-up.

Results and Discussion

Since this project consists of two parts of methodology, then the results also can be divided into two parts as fuel properties and engine performance. The details of the results were discussed in the following sections.

Fuel Properties

Figure 2 illustrates the density of all the fuels used in this project. Based on this figure, the results show that the density of WCO is the highest and the lowest density is found to be RON 95 (petrol). This results is obvious and it is matched with the other related research works [4]. As for the fuels blend, the density reduce gradually as the volume of the RON95 is added into WCO from 5 to 25 percent. This result also matched with the theoretical understanding and purpose of this project; lower density since lower density of the RON95 will reduce the higher density of WCO for their blend respectively. However, the density of all fuels blend is still higher than the density of the diesel and the difference range between 6.1% and 2.7% of R25W75 and R05W95 from diesel.

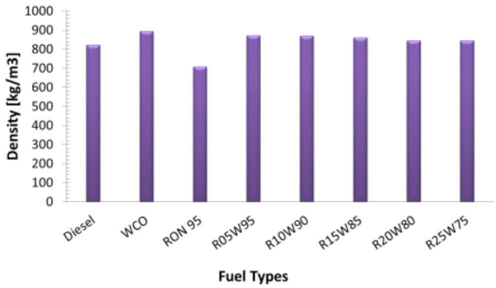

Figure 2: The density of the fuels.

The caloric value of the fuels is illustrated in Figure 3. Based on this result, the highest and lowest caloric value is belongs to diesel and WCO respectively. Interestingly, the result also shows that the caloric value for RON95 is lower than diesel. This result actually matched with the related research work and higher caloric value of diesel than RON95 is due to the improvement technology on diesel fuel especially for ULSD [3, 13]. Note that, this reason also contributed to the increase number of diesel engine used for passenger car in Europe. As for the fuels blend, apparently the caloric value increased as the percentage of RON95 increase in the blend. However, the caloric values of the fuels blend still lower than diesel and ranging between 7% and 8.8% of R25W75 and R05W95 from diesel.

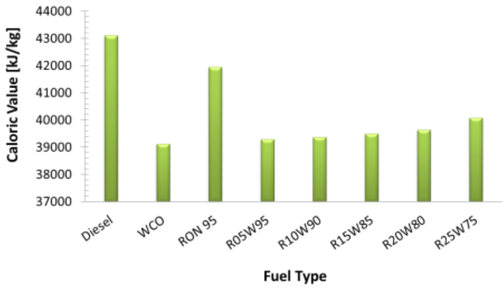

Figure 3: The caloric value of the fuels.

Engine Performance

As explain before, the engine performance characteristics were measured through the engine dynamometer. During the experiment, no unusual engine behaviour was detected. Also, the problem of fuel filter and injector clogging that have been worried by some researchers [10] were not experienced in this research work. This condition is expected because the WCO were properly filtered before blended with petrol fuel.

As for the results under this section, it consist of the basics result parameters for engine performance including the brake specific fuel consumptions (BSFC), engine efficiency, engine power and exhaust temperature. The details of each parameter are explained in the following section.

Brake Specific Fuel Consumptions (BSFC)

The results of BSFC versus engine speed for all run are illustrated in Figure 4. Based on the pattern shown on that figure, the BSFC gradually decrease from 1500 rpm until approximately 2250 rpm and then increase again when the engine speed is increased. This pattern is generally similar to the theory [14] and other related research work [1, 15].

Comparing the results among all runs, it is found that higher percentage of WCO in the fuel blend (R05W95 – 5% of RON95 and 95% of WCO) is producing good results at higher engine speed (3000 rpm), not at lower engine speed. At lower engine speed (1500 rpm), lower percentage of WCO in the fuel blend (R25W75 – 25% of RON95 and 75% of WCO) is producing good results. This result is probably due to high engine speed, the combustion temperature is higher and reduces the viscosity of the WCO since the density of fuel is inversely proportional to the temperature [16] and with the additional of oxygen content in the WCO [17], it produce better combustion and produce lower BSFC. As at lower engine speed, higher percentage of RON95 is expected helping the combustion process.

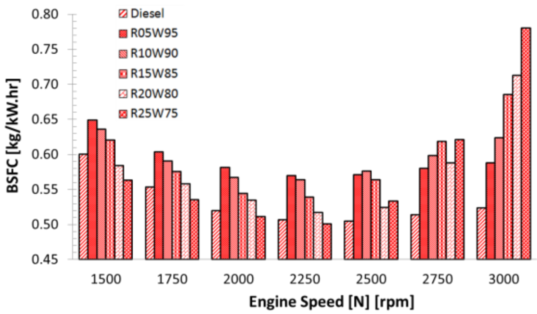

Figure 4: The BSFC versus engine speed for all run.

Engine Efficiency

Figure 5 shows the results of engine efficiency versus engine speed for all run. The pattern shows on this figure is typical with other related research work since the efficiency is kept increasing from lower engine speed until mid-range and gradually decrease toward higher engine speed [8, 18].

The results of engine efficiency also shows that higher content of WCO produced higher efficiency at higher engine speed as compared to the lower engine speed. Similar explanation as BSFC, at higher engine speed is expected contributed to this results, where at higher engine speed the combustion temperature is higher and reduces the viscosity of the fuel blend and with the aid of oxygen content, it produce higher in-cylinder combustion and higher engine efficiency.

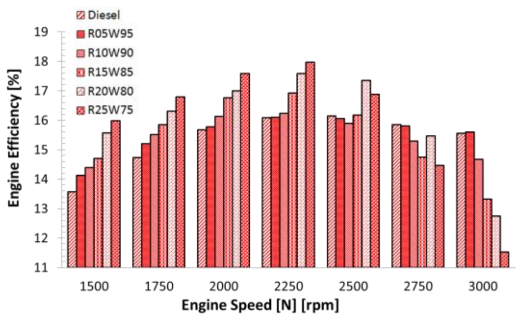

Figure 5: Engine efficiency versus engine speed for all run.

Engine Power

As for engine power, the results is portrayed in Figure 6 and plotted also versus engine speed. Based on the figure, all of the engine power is increased gradually as engine speed is increased. This pattern is considering behaving as per theory since the experiment were conducted at constant engine load [14, 19]. These results prove that the experiments were conducted in a proper manner.

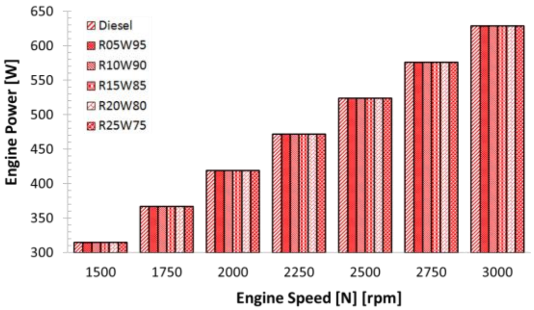

Figure 6: Engine power versus engine speed for all run.

Exhaust Temperature

Figure 7 illustrated the results of exhaust temperature for all runs against engine speed. Based on the result, the exhaust temperature increase as engine speed is increase. This condition is considered normal behaviour of the exhaust temperature since higher engine speed required higher fuel consumption to be burnt [20]. The results shows that higher volume of RON95 stimulates the combustion and produce higher exhaust temperature. The results also shows that higher WCO content has lower exhaust temperature due to higher density as shown in the results of density above.

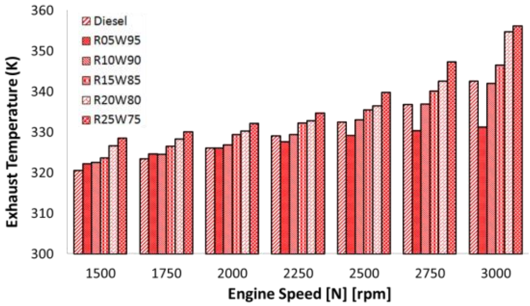

Figure 7: Exhaust temperature versus engine speed for all run.

Overall Engine Performance

Based on the results of BSFC, engine efficiency, engine power and exhaust temperature presented above, the overall performance of CI engine run with blended WCO and petrol fuel (RON95) is still lower than the one run with diesel fuel. This is expected because of the properties of the fuel blends in term of density and caloric value still lower than diesel fuel.

In term of WCO usage, this research found that lower percentage of WCO is better at lower engine speed while higher percentage of WCO are better at higher engine speed. Therefore, further research is recommended to utilize the use of WCO as fuel in CI engines since it has potential.

Conclusion

Due to the receding supply of the petroleum based fuel, this project attempted to utilize the WCO as fuel for CI engine. The WCO was blended with the petrol fuel (RON95) in order to reduce the viscosity and density in the range of 5 percent to 25 percent volume based. The density and caloric value of each of fuel blend ratio were measured. The fuel blends were then used as fuel for CI engine and run on single cylinder CI engine. By using engine dynamometer, the BSFC, engine efficiency, engine power and exhaust temperature for each run were measured.

Based on the results presented in this research work, it is found that the lower volume percentage of WCO (i.e. R25W75) is suitable to use at lower engine speed and higher volume percentage of WCO (R05W95) is suitable for higher engine speed. This condition is expected because of, at lower volume percentage of WCO, the density is lower, thus the fuel blend is much prone to evaporate, diffuse, mixes and combust as compared to the higher volume percentage of WCO. Conversely, at higher engine speed, the engine temperature is higher and the effect of this temperature reduces the viscosity of the fuel. With the help of oxygen content present in the WCO in higher volume, the combustion is better.

Upon considering all of the results presented above, this research conclude that the WCO still could not be used by only blending with petrol because the results is still poorer than diesel fuel. Therefore, further research is recommended to find suitable solution to utilize the WCO as CI engine fuel.

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