

Preheated Waste Cooking Oil and Diesel Blend Fuel (WCO50D50) Using Copper Coil Wrapping Around Exhaust Pipe

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ABSTRACT

Petroleum-based fuel is an energy source that powers various means of transport; in this project to fuel internal combustion engines. The petroleum-based fuel which can be classified as a non-renewable energy sources. It is also considered not to be easily reproduced and unable to meet future demand. Waste cooking oil (WCO) is one of the promising resources of alternative fuel that can be used as biofuel, as it can be recycled from the cooking of food activity in daily life. However, WCO has drawbacks which are higher density and viscosity than conventional diesel fuel. Due to these problems, this project investigated the effect of blending 50 percent WCO and 50 percent conventional diesel (called WCO50D50) i.e. to reduce the viscosity and density of WCO. In order to further reduce the viscosity and density of the WCO50D50, this project also studied the effectiveness of preheated WCO50D50 using copper tube wrapping around exhaust pipe and determine the optimization of the copper tube turn between two and ten turns. Upon analysis through the experimental procedure on the single-cylinder diesel engine, this project found that this method is working although the effectiveness of copper pipe wrapping around the exhaust pipe is considered low.

Keywords: *alternative fuel, waste cooking oil, fuel blend, diesel engine and heat recovery.*

Introduction

Waste cooking oil (WCO) mainly refers to frying and cooking oil used at high temperatures, edible fat mixed within kitchen waste and oily wastewater directly discharged into the sewer [1]. A large amount of waste cooking oil is generated every day in the world from households, restaurants, food processing industries and fast food shops. For example, in Japan, the waste cooking oil was generated nearly 0.4–0.6 million tons yearly [2]. Thus, the reuse of WCO is a way of minimizing environmental impacts and consequently the expenses related to combating pollution generated in the maintenance of basic sanitation systems [3].

Presently, many studies about utilizing WCO blend with diesel to be used as an alternative fuel has been done by worldwide researchers. As a generally positive result from those researches, the diesel engine generally can be run using blended fuel of WCO and conventional diesel fuel without any major engine modifications. However, negatively, the result of the engine performance of the diesel engine is quite lower with using WCO-based fuel especially WCO-diesel blend fuel as compared to the similar engine run on conventional diesel as a fuel [4]. According to H. Hazar and H. Aydin [5] that based on their research on the performance and emission evaluation of a compression ignition (CI) engine fuelled with preheated raw rapeseed oil and diesel, blends was carried out the result of the engine performance such as brake specific energy consumption and brake thermal efficiency was improved by using WCO blend that preheat at a variable temperature than without preheated it.

The study made by D. Capuano *et al.* [4] reported that the carbon monoxide (CO) emissions were reduced at an increasing temperature of WCO blend than without preheating the fuel blend, but the CO emission is still higher than diesel. This is due to the WCO had higher viscosity and density which make poor fuel atomization during fuel injection. Correspondingly, that research also reported that the power and torque were also reduced to the engine run with WCO blend as compared to the one run with conventional diesel. The main reason for this problem is pointed to the lower calorific value of the WCO along with the lower viscosity and density of the WCO blend. Therefore, based on the observation from the literature, the preheating or blend with conventional diesel fuel of WCO can adapt to reduce the viscosity and density.

In general, the literature shows that a large amount of research has been done into converting WCO to be a biofuel, specifically alternative fuel for diesel engines. However, to the extent of the author's knowledge, limited studies has been found to achieve the absolute winner when compared to the diesel engine run with conventional fuel.

Because of that, this project has investigated the newly blended fuel of 50% WCO and 50% of conventional diesel fuel, as another option for

alternative fuel which namely as WCO50D50, based on its volumetric blended ratio. This is to utilize 50 % of WCO to make it worth reducing the usage of conventional diesel fuels. Furthermore, this project also will further reduce the viscosity and density of the WCO50D50. The heat from the exhaust that generally considered as waste will be used as a heat source to preheat the WCO50D50. The idea is then verified experimentally using the single-cylinder diesel engine model YANMAR L70.

Methodology

In this project, the methodology was divided into two parts. The first one is the fuel samples preparation and the second one is the engine testing. As for sample preparation, the WCO sample was collected from Secret Recipe restaurant located at AEON Mall, Shah Alam, Selangor. This restaurant used palm oil-based cooking oil to cook several dishes served in the Secret Recipe menu. Generally, this restaurant has mixed the WCO after the palm oil-based cooking oil was used to fried the chicken, fish, meat, wanton, popiah, shrimp and sweet potato. So that, the WCO sample in this project can be considered as mixed type WCO with all frying food types.

The WCO sample was then placed at the lab and observed in two weeks. During the observation, the WCO is found to had impurities on the top and bottom of it. This impurities generally contain the residue food and fat that have been used to fried it before. To remove the impurities, the WCO was filtered using two layers of fabricated filter made from normal white fabric cotton. As conventional diesel, it was brought from a local petrol station. The sample of WCO50D50 was prepared by adding 50% v/v of the conventional diesel with 50% v/v of WCO. The total volume of WCO50D50 is 20-litre which contains 10-litre of WCO and 10-litre of conventional diesel. For the blending method, the splash mixture method was used where the 20-litre fuel blend that has been placed in the transparent container was shaken manually. This method was selected for the mixing process due to its simplicity, ease to perform without any equipment and did not involve any monetary cost of the blending process. Observations were made on the fuel samples after splashing the mixture between the WCO and the diesel fuel to investigate the homogeneity of the mixture. It was found that they were well fused without separation between WCO and diesel fuel. This condition is expected because the physicochemical properties of WCO are similar to diesel fuel [6].

After that, the fuel properties such as kinematic viscosity, calorific value and density were determined on samples of diesel, WCO and WCO50D50. The calorific values of these fuels were measured using Oxygen Bomb Colorimeter (Model C200). The kinematic viscosity value was measured at 40°C using Anton Paar AMVn viscometer. The temperature chosen to measure the kinematic viscosity was established by the literature [7]. The density of the fuel sample was determined by using basic method of the

mass of the sample divided by its volume [8]. For this project, the digital weight machine where a 200-ml fuel sample was placed in measuring beaker and measured the mass of the fuel sample. Then, the mass of the fuel sample is divided by its volume to calculate the density of the fuel sample and converted into the unit of kg/m^3 . This process is repeated for diesel, WCO and WCO50D50. By that the first part of the methodology; the fuel samples preparation is completed.

For the second part of the methodology; engine testing, this project used a single-cylinder, air-cooled and the direct injection diesel engine (YANMAR, model L70N6-PATMYI). This diesel engine produced maximum engine power of 6.7 horsepower at 3600 rpm and it was coupled with a 5 kW electrical dynamometer. The engine setup (see Figure 1), it's started with the modification of the fuel tank where in this project dual fuel tanks are required. One was used for the conventional diesel fuel and the other tank was used for the WCO50D50. This dual fuel tanks system was then controlled using a control valve to select the preferred type of fuel to run the engine. Furthermore, the fuel line was set up by connecting it through a copper tube that is wrapped around the exhaust pipe before it goes to the fuel injector. This setup is used to preheat the fuel using waste heat exhaust gas to further reduce the density and viscosity of WCO50D50 as mentioned earlier.

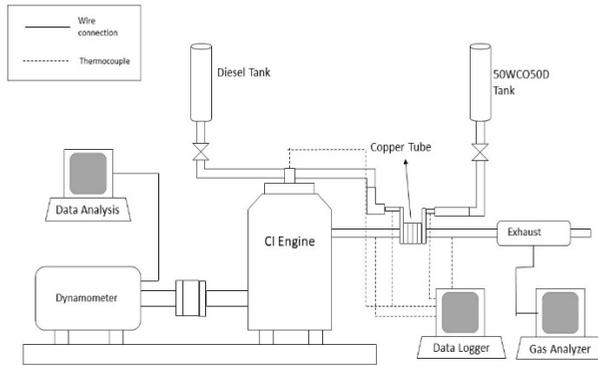


Figure 1: Schematic diagram of the experimental setup.

For this project, five sets of the copper tube wrapped around the exhaust pipe were made (see Figure 2) in order to experimentally investigate the optimum number of turns of the copper tube wrapped around the exhaust pipe so that the viscosity and density of the WCO50D50 will be further reduced. They are 2 turns, 4 turns, 6 turns, 8 turns and 10 turns and they are named C2, C4, C6, C8 and C10; respectively. Finally, the thermocouples were placed before and after the copper tube to measure the increment of the heat that can be recovered by this system from the heat of exhaust gas. The portable gas

analyser from KANE Automotive was used to measure the CO gas emission from the experiment later.

For the experimental procedure, the engine was started with the conventional diesel fuel until it achieved engine operating temperature. The experiments were conducted at a constant engine speed of 1500 rpm with various engine loads from 1-Nm to 5-Nm. The data from the run of conventional diesel fuel was then recorded as baseline data. The same experimental procedures were applied to the fuel of WCO50D50, WCO50D50C2 until completed the five sets of copper tubes that have been prepared earlier using the same set-up.

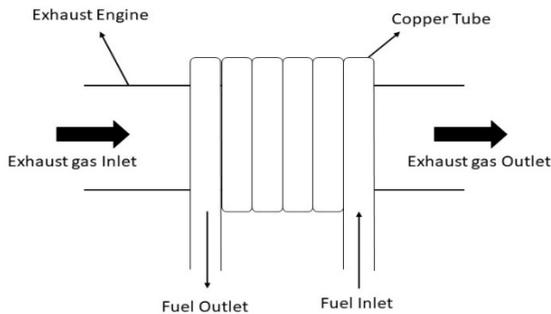


Figure 2: Schematic diagram of the copper tube wrapped around the exhaust pipe.

Results and Discussion

In order to study the effect of using copper coil wrapping around the exhaust pipe, this project presented the results of fuel properties, preheat the WCO50D50, brake specific fuel consumption and CO emissions.

Fuel Properties

The result of the density measurement for all fuel samples is illustrated in Figure 3. Based on that figure, the highest density was recorded at WCO with the value approximately 905 kg/m^3 and the lowest density was recorded at diesel with the value of approximately 822 kg/m^3 . Based on that, there were approximately 83 kg/m^3 of density difference between WCO and diesel fuel. This result is obvious and it matches with the aim of this project whereby low volatility of WCO will be mixed with higher volatility of diesel. The result on fuel mixing also showed an expected result in which when diesel was added into less WCO in volume base, the density gradually reduced.

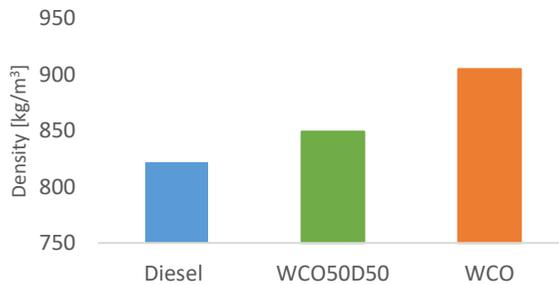


Figure 3: The measured density of conventional diesel, WCO50D50 and WCO.

Kinematic viscosity is the measure of a fluid’s inherent resistance to flow when no external force, except gravity, is acting on it and while kinematic viscosity is depending on fluid density as compared to the dynamic viscosity that is not dealing with density [8]. The kinematic viscosity in this project is measured at 40°C as seen Figure 4 which in agreement with other reported works [7, 9, 10]. The higher viscosity was recorded with WCO and the lowest kinematic viscosity is recorded with the conventional diesel fuel. The WCO50D50 is lies between conventional diesel fuel and WCO as expected. Thus, the blended fuel of WCO and conventional diesel fuel was successfully reducing the kinematic viscosity of the fuel. According to Cheung, C.S., *et al* [11], high viscosity has been observed to negatively affect the air-fuel mixing and evaporation process. With this result of reduction of the kinematic viscosity, it is expected better air-fuel mixing and evaporation process as compared to WCO.

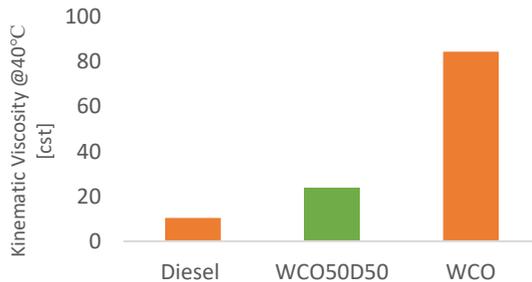


Figure 4: The result of kinematic viscosity for all fuel samples

The calorific is the amount of energy released when a known volume of gas is completely combusted under specified conditions [12]. In this project, Figure 5 shows the results of the calorific value of all fuel samples. Based on the result presented in Figure 5, the highest calorific value was recorded at

conventional diesel fuel and the lowest calorific value was recorded from the WCO sample. When both fuels were blended at an equal ratio, the calorific value lies in between them. According to Chauhan *et al.* [13], chemically bonded oxygen in WCO will lower the heating value by about 10%.

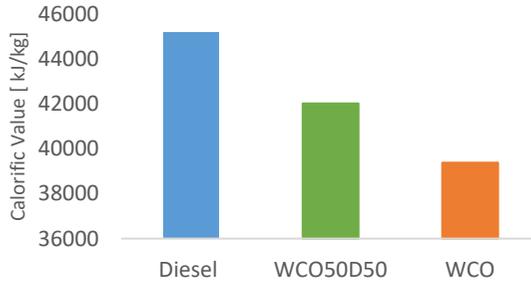


Figure 5: The result of calorific value for all samples.

Preheat the WCO50D50

Figure 6 shows the results of inlet temperature at fuel injector that being monitored using data logger while fuel is injected during engine operation. Based on the results presented in Figure 6, indicates that wrapping copper pipe around the exhaust pipe was successfully preheated the WCO50D50. Based on that result, the highest recorded temperature is with WCO50D50C10 with the value of 41.3°C as compared to 33°C without using copper pipe wrapping around the exhaust pipe. This result was recorded at 5-Nm load of engine testing. From that, approximately 8°C is increased. According to the literature, the preheated temperature at the fuel injector for higher viscous alternative fuel is better when the temperature can reach between 92°C and 100°C [5, 14]. For this project, the maximum value is 41.3°C, which is very low as compared to the requirement set up by the literature. Low heat recovery from this project is expected due to the losses of heat between copper pipe and fuel injector where the line is approximately 53 cm. For this project, the line is not insulated. Also, the contact area between the copper pipe and the exhaust pipe is not perfect as having only a small area of contact between them since the copper pipe is round in shape. Therefore, for future improvement, it is suggested that to improve the contact between exhaust pipe and copper pipe of the fuel line, so that the fuel inlet temperature can be increased and achieved the objective of reducing the viscosity and density of WC050D50.

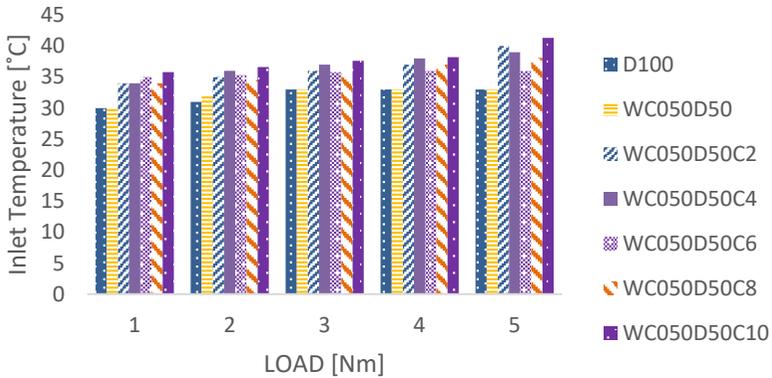


Figure 6: The temperature at the fuel injector.

Brake Specific Fuel Consumption (BSFC)

Figure 7 illustrate the results of BSFC for all engine run as indicates in its graph legend. It is observed that BSCF for all fuels increased as the engine load increases. At higher engine loads, diesel had the lowest BSFC but for the constant speeds at 1500 rpm, the BSFC for blend WCO50D50C10 had the lowest result of BSFC. For the load between 1-Nm and 5-Nm, the BSFC for blend WCO50D50C10 is also recorded a lower value than other preheat WCO50D50. Besides, at both low and high engine speeds, the BSFC of blend WCO50D50 without preheat is just slightly higher compared to diesel which is nearer to the BSFC of diesel. Based on this result, preheated WCO can improve the engine performance due to better vaporization while as result show lower BSFC values than blend without preheated. The result obtained here is in agreement with Yilmaz *et al.* [15].

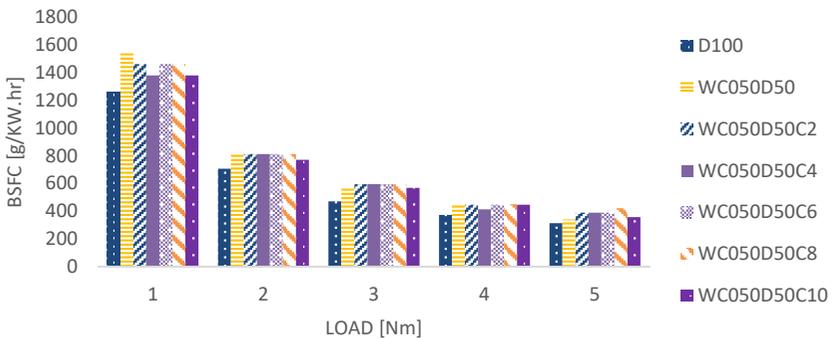


Figure 7: The BSFC for all engine testing.

Carbon Monoxide (CO) Emission

CO is one of exhaust emission which is harmful gas to the environment as well as a human being. In this project, the expected results of CO with the preheating coil are lower than those carried out with diesel fuel to study the effectiveness of the preheating coil to reduce the CO emission. In Figure 8, the results of CO emissions from this project shows the inconsistency of result due to lack of apparatus device measurement. Therefore, some data could not be detected by the measuring instrument. However, general trends resulting from these experiments can still be seen. The higher CO emission was recorded with WCO50D50 for all load i.e. without preheating the fuel. When the fuel is preheated, then the value of CO was reduced. The trend of preheating the fuel is reducing the CO value is in lies with the results reported by S. Bari and T.H. Lim [14] in their research title of “Effects of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine,”. This result shows that, preheating the fuel blend can reduces the CO emission.

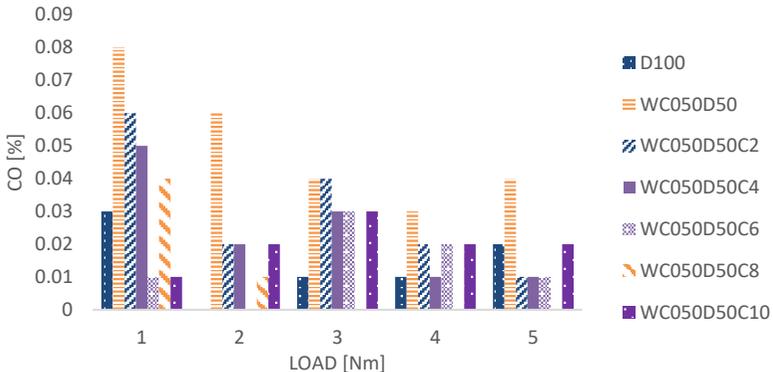


Figure 8: The results of CO emission for all engines run in this project.

Conclusion

The main objective of this project is to investigate the effect of CI engine performance and emissions when running with preheat fuel of WCO50D50. The WCO sample was collected from the local restaurant and filtered with cotton mesh before being blended with conventional diesel fuel in order to reduce its viscosity and density. The fuel properties of diesel, WCO and WCO50D50 were then measured. After that, all the fuel samples including conventional diesel fuel are tested on single-cylinder diesel engine coupled with an electric dynamometer with a constant speed different load. The WCO50D50 was preheated by using a copper tube which to reduce of viscosity and density of fuel and the results of fuel inlet temperature were recorded and

presented. For the engine performance and emissions such as BSFC and CO were present.

According to the observation during the experiment, the blended fuel is run without any problem. Based on the result presented as per engine setup in this project, it can be concluded that WCO50D50C10 had highest improvement than other setup. Nonetheless, its improvement is still below the baseline result of the one run with diesel fuel. Therefore, this project acknowledges that WCO50D50C10 prepared by this project were not suitable to be a replacement for conventional diesel fuel.

The result of WCO50D50C10 might be better if no losses between temperature output copper tube and inlet fuel engine due to the no insulate and long-distance pipe. Therefore, further research is recommended to find a suitable solution to utilize the WCO as CI engine fuel. However, there is hope in this idea to preheat the alternative fuel by recovering heat waste without using an external heat source. Now, a new idea needs to be presented in order to overcome the problem with the current engine setup.

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