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Effect of Biodiesel and Radiator Tube Heater on Fuel Consumption of Compression Ignition Engine

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Abstract. The growing demand of CI engine for automobiles impacts to the increasing of diesel fuel consumption. The biodiesel fuel and heated fuel in diesel engine are considered as an alternative solution to addres the problems in increasing demand of diesel fuel.This research aims to investigate the effect of adding biodiesel into diesel fuel and fuel heating through a square finned tube in radiator upper tank on fuel consumption in the CI engine. The experimental studies were conducted on 4 cylinder CI engine car using SNI 7554:2010 standard test. The amount of biodiesel added into diesel fuel is varied with a percentage of 0% to 30%. This work also analyzed the effect of different values of the distance between square fin, which are 10 mm, 20 mm, and 30 mm. It can be concluded in this study that incorporating biodiesel in the diesel fuel improves the fuel efficiency. The most efficient consumption is in addition of 15% biodiesel in the amount of 266.7 ml/km. Moreover the fuel heating also affect fuel efficiency of the CI engine. It was found that utilizing a 30 mm square finned tube radiator result in greater fuel consumption rate. Fuel heating can affect the fuel savings resulting from the addition of biodiesel. The most cost-effective consumption is the addition of 20% biodiesel in diesel fuel and heating with 30 mm fin spacing of 206.4 ml/km. By knowing the effect of biodiesel in diesel fuel and fuel heating with the distance between square fin used, it is possible to design an engine system with high fuel efficiency CI engine car.

1. Introduction

The growing number of vehicle production in this recent years increases the national fuel consumption. It has been reported that total the most energy consumption during 2000 to 2014 is carbon based fuel (gasoline, diesel oil, kerosenen, fuel oil, aviation fuel and avgas) with a total of 308 million SBM in 2014 [1].

The biodiesel fuel added in diesel fuel is considered as an alternative solution to address the problems in increasing demand of diesel engine. Based on the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia number 25 of 2013, the diesel fuel should be mixed with neither biodiesel, bioethanol or pure vegetable oil [2]. Biodiesel is an alternative fuel that can improve performance and produces low emission level [3]. The result of biodiesel addition in diesel fuel to determine the amount of fuel consumption. Previous study revealed that adding 20% biodiesel in diesel fuel result as the most efficient fuel consumption[4]. Another study supported that report and confirmed a difference by 6.44% from standard fuel with incoporated biodiesel [5]. It was also reported that the average percentage of the specific fuel consumption can be reduced by 32.04% [6]. The incorporation of biodiesel in diesel fuel can lower the level of opacity in diesel cars with the percentage of 39.025% by mixing 30% biodiesel in the diesel fuel [7]. The percentage of biodiesel in

diesel fuel is only allowed to a certain degree as an excessive amount biodiesel will decrease the engine torque and power [8].

Another alternative for improving the fuel efficiency is by fuel heating before combustion (*pre heater*) since the heating tube will produce a good heat transfer [9]. Fuel heating will improve the combustion process because decreasing the fuel viscosity and density. Therefore, it will increase the performance of abduction process in the combustion chamber [10,11]. The fuel heating could be implemented by applying a finned tube in the upper tank of the car radiator. The upper tank heat of the car radiator is aim to increase the heat of the fuel. It has been reported that fuel heating through tranversal finned tube can affect CO and HC levels [12].

The fuel heating tube in the radiator provided a significant reduction in fuel consumption where a heating tube with a 10 mm fin improved the fuel consumption occurs in by 5.632%[13].

In another experimental study on the application of square finned tube on radiator upper tank reported the fuel consumption of 37.453 x 10^{-3} per cycle after implementing a 30 mm diameter finned tube. The fuel consumption improved by 2.022% from the one with unheated fuel [14]. However, those studies were mostly performed in the laboratory scale which requires further research to determine the result of engine performance in the wider application.

2. Methods

2.1. Experimental equipment

Equipment in this research include measuring cups, and radiators that have been varied with finned tubeand tube without fins.

Table 1. Engine Specification

Specification	Detail
Category of Vehicle	M1
Type Engine	OHV
Numbered frame	TBR51
Cylinder Volume	2.449cc
Fuel	Diesel Fuel
Transmission	Manual, 5 speed
Diameter	93 *mm*
Stroke	92 *mm*
Compression	17,9
Weight Vehicle	2150 *kg*
Power	80/3, 500PS/rpm
Torque	19.5/1, 800 Kgm/rpm

Table 1 shows the engine specifications used in the research. CI engine car used was a 4-cylinder OHV numbered frame TBR51; Diesel fuel; Cylinder capacity: 2,449 cc; Diameter: 93 mm; Stroke: 92 mm; and has a compression ratio of 17.9.

2.2. Experimental description

The independent variables in this research which are (a) Variation of amount of biodiesel to diesel fuel are 0%, 5%, 10%, 15%, 20%, 25%, and 30%. (b) Variations of the distance between square fins are 10 mm, 20 mm, and 30 mm.

The dependent variable for this research is fuel consumption in test drive of CI engine car, where the test drive is performed on Solo-Kertosono Boyolali toll road as far as 2.7 km.

The control variables in this research include (a) diesel fuel, (b) biodiesel produced by a local company in Klaten, (c) vehicle and environmental conditions in accordance with SNI 7554:2010[15], (d) the radiator fluid that is equal to each test.

This research aims to determine the effect of biodiesel addition in diesel and diesel fuel and the heating through square finned tube in the radiator upper tank to fuel consumption in the CI engine car road test, which is compared with the standard fuel consumption condition.

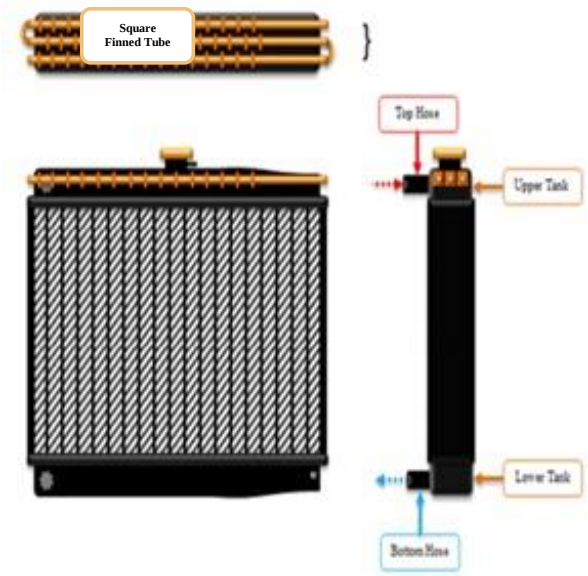

Figure 1. Design Radiator Research

The preheat system is a tube-heater installed inside of the radiator upper tank as shown in Figure 1. The side of the upper tank has been drilled to create a hole, inside which the tube is put. This tube is heated by hot water from the radiator. The hot water comes from the water jacket in the engine body. It is carrying the heat generated there as the engine runs. It flows to the top house in the radiator upper tank. The hot water then heats the tube, and the diesel fuel inside, before returning to the lower tank. The hypothesis of this experiment is that heating the diesel fuel in this way will increase its efficiency of combustion and thus decrease fuel consumption. This research used previously varied radiators.

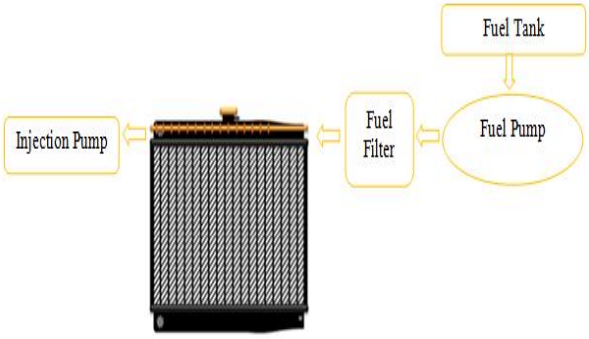

Figure 2. Fuel Heating Flow Scheme

In this research, an experimental method in a compression-ignition engine is used to examine some variables that might increase the efficiency and reduce the fuel consumption, in particular, the effects of adding heat to a blended fuel. The fuel, which in this experiment includes pure diesel fuel and biodiesel blended with diesel fuel, is directed to a preheat system after going through the fuel filter and before entering the combustion chamber, as shown in Figure 2. After being heated, it flows to the injection pump, where fuel and air are mixed. From the injection pump, the mixture of fuel next flows to the combustion chamber through injector.

The first step of the experiment is to examine the fuel consumption in a normal engine without the tube-heater, that is, without a fuel heating condition. The fuel flows from the tank to
The injection pump and burns in the combustion chamber normally. This gives a basis for fuel consumption with which to compare the heated fuel condition.

3. Results and discussion

The data of fuel consumption is obtained by way of test drive of the vehicle with a distance of 600 m acceleration trajectory, trajectory of the test 2 km, and trajectory deceleration 100 m. The speed of the test vehicle at the time of the test is 60 km/h in a constant state. The result of fuel consumption is measured by using a measuring cup.

The following are the data of the test result of the effect of biodiesel addition to diesel fuel and the application of square finned tube in the radiator upper tank on fuel consumption in the test drive of diesel car.

Table 2. Test data of fuel consumption

Fuel Consumption (ml/km)					
X_1 \ X_2	$X_{2,1}$	$X_{2,2}$	$X_{2,3}$	$X_{2,4}$	$X_{2,5}$
0	400	343,2	369.1	350.6	324,7
5	290,1	313,6	312,3	302,5	301,5
10	281,5	282,7	300	286,4	276,6
15	266,7	267,9	282,7	270,1	227,2
20	302,5	240,7	253,1	227,1	206,4
25	321	304,9	288,9	295,1	240,7
30	344,4	325,9	300	307,4	309,9

Explanation:
X1 : Mixed biodiesel (%)
X2 : Heating Fuel
$X_{2,1}$: Without Heating
$X_{2,2}$: Plumbing Heating
$X_{2,3}$: Heating of finned tube with a distance of 10 mm fin
$X_{2,4}$: Heating of finned tube with a distance of 20 mm fin
$X_{2,5}$: Heating of finned tube with a distance of 30 mm fin

3.1 Pure diesel fuel

Figure 3 shows that the standard fuel consumption in CI engine car is 400 ml/km. The most efficient fuel consumption is achieved in heating a square finned tube 30 mm distance of 324.7 ml/km. Fuel heating with tube-heater with a spacing of between 10 mm and 20 mm fins shows an increasing of fuel consumption rate compared to tube-heater with 30 mm fin spacing. This is because the height fuel temperatures causes fuel to reach faster self-ignition conditions which led to an increase of fuel consumption.

3.2 Biodiesel blends in diesel fuel

Figure 4 shows that the addition of biodiesel in diesel fuel and heating can decrease the level of fuel consumption. The best configuration with in the variables studied is the addition of 20% biodiesel and heating with tube-heater with 30 mm distance of fin which result 206.4 ml/km of fuel consumption rate. There was a decrease in the rate by 193.6 ml/km or 48.4% compared to standard fuel system.

The mixture of biodiesel and diesel fuel will increase the cetane numbers[16] which produced a low flash point, so that the fuel in the combustion chamber bums faster. This leds to more efficient of the fuel consumption in the engine. In the other hand, the heated fuel results specified level of viscosity and evaporation on the fuel which generated more homogeneous fuel and air. The improvement of the homogeneity level of will accelerate the combustion process better which leds to decreasing of the fuel consumption[17]. A combustion of biodiesel and heated fuel produce better fuel consumption rate.

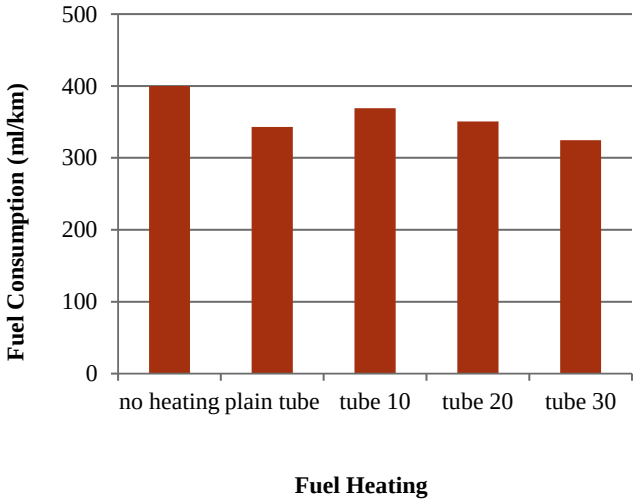

Figure 3. Heating with pure diesel fuel

The addition of 5% biodiesel in fuel and without heating decreased from 400 ml/km to 290.1 ml/km. There is an increase in consumption as fuel levels increase. At 5% biodiesel variation the amount of fuel consumption decreases with heating with no fins, heating with square finned tube spacing of 10 mm, heating with square finned tube spacing of 20 mm, heating with square finned tube spacing of 30 mm, and the most economical fuel consumption on unheated step at 290 ml/km.

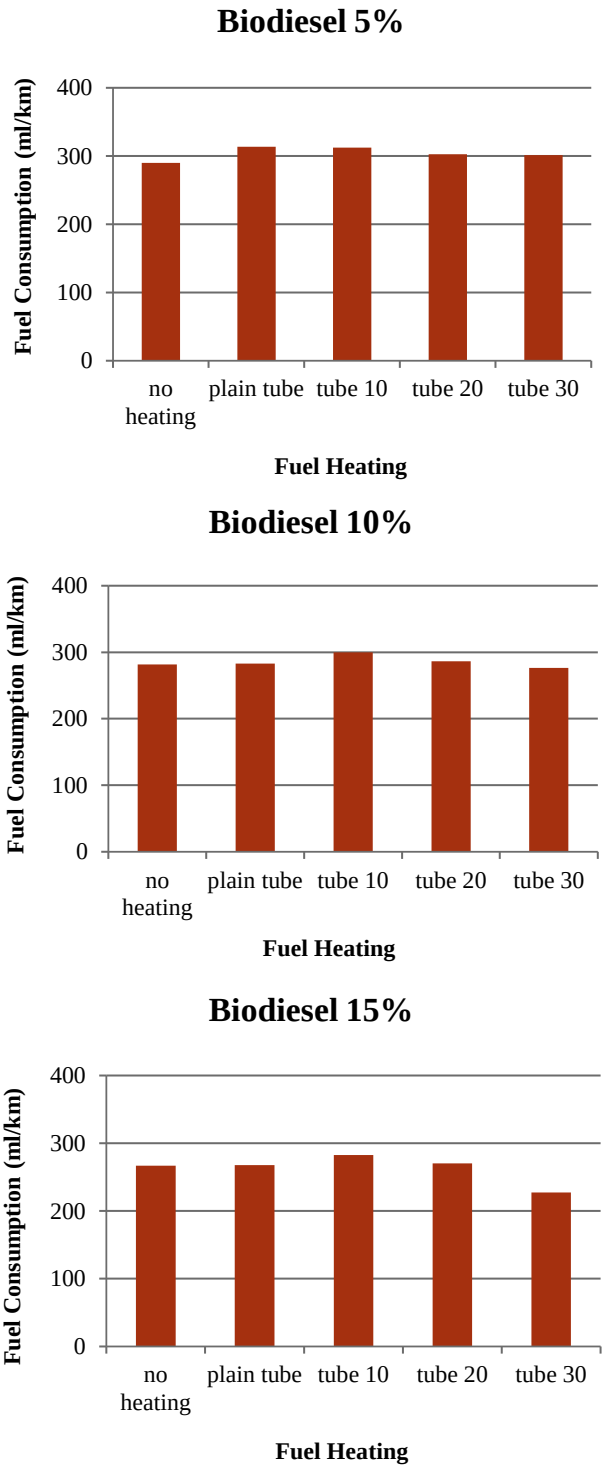

Figure 4. Biodiesel Blends in Diesel Fuel

In the variation of the biodiesel content 10% the amount of fuel consumption decreases with the unheated stage, heating with square finned tube spacing 10 mm, heating with square finned tube spacing of 20 mm, heating without fins, and 30 mm. The most economical fuel consumption on finned tube heating distance 30 mm at 276.6 ml / km.

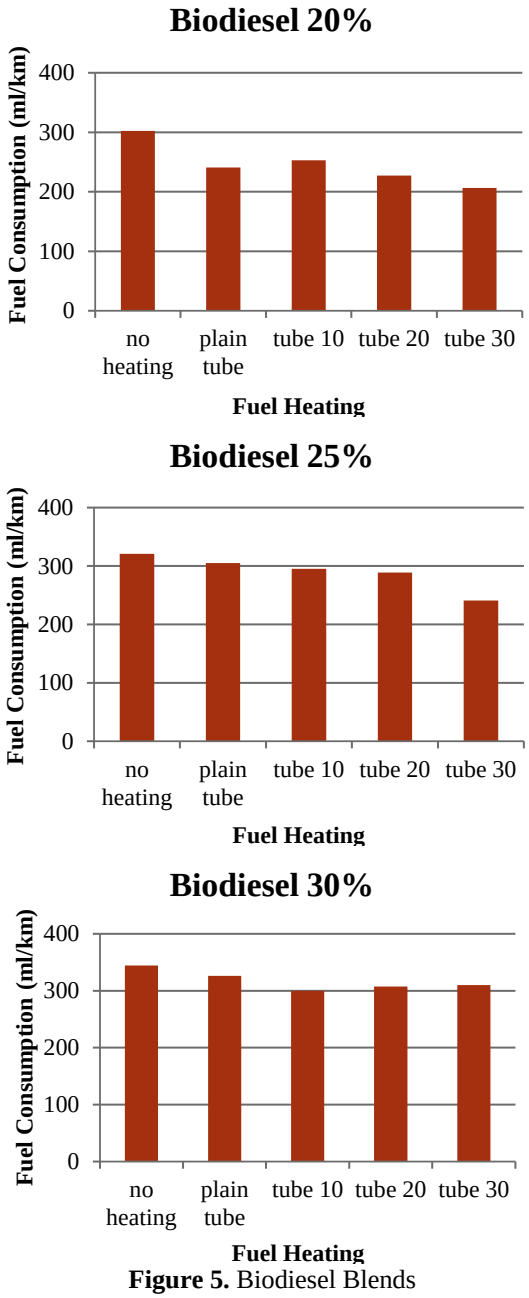

Figure 5. Biodiesel Blends

At 15% biodiesel variation the amount of fuel consumption decreases with unheated step, heating with square finned tube spacing of 10 mm, heating with square finned tube spacing of 20 mm, heating

with no fins, and the most economical fuel consumption on finned tube heating distance 30 mm at 327.2 ml/km.

In the variation of biodiesel content 20% the amount of fuel consumption decreases with unheated stage, heating with square finned tube spacing of 10 mm, heating without fins, heating with square finned tube 20 mm spacing and the most economical fuel consumption on heating square finned tube30 mm of 206.4 ml/km.

In the biodiesel that content variation 25% of the total fuel consumption decreases with the unheated stage, heating without fins, heating with square finned tube 10 mm spacing, heating with square finned tube 20 mm spacing and the most economical fuel consumption on heating square finned tube 30 mm of 240.7 ml/km.

In the variation of biodiesel content 30% the amount of fuel consumption decreases with the unheated stage, heating without fins, heating with square tube 20 mm distance, heating with 30 mm diameter square finned tube and the most economical fuel consumption on heating square finned tube10 mm of 300 ml/km.

3.3 Comparison of fuel

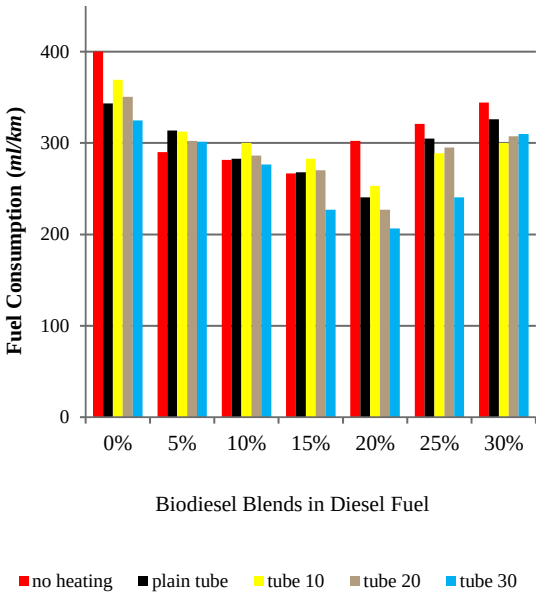

Figure 6. Comparison of Fuel Consumption from Biodiesel Blends in Solar Fuel

Figure 6 shows the comparison of the result data of all tests. The data can be seen that the fuel consumption in the CI engine car will decline as the addition of biodiesel in diesel fuel. Levels of 25% and 30% biodiesel in diesel fuel experienced an increase in fuel consumption, it is seen figure 5. The best consumption of biodiesel ratio in diesel fuel 25%:75%. This research uses plain tube heating and heating with finned tube, where fins spacing is 10 mm, 20 mm, and 30 mm. Increased warming that occurs causes consumption level is increasingly wasteful.

4. Conclusion

Incorporating biodiesel in the diesel fuel and heating fuel decreases the fuel consumption on CI engine car. The most cost-effective consumption is the addition of 20% biodiesel in diesel fuel and heating with 30 mm fin spacing of 206.4 ml/km. There was a decrease in fuel consumption rate by 193.6 ml/km or 48.4% of the standard consumption.

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