Spray Characteristics at Preheating Temperatur of Diesel-Biodiesel (*Calophyllum inophyllum*)-Gasoline Fuel Blend

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ABSTRACT

Technological developments in diesel engines require improvements to the fuel injection system to meet the criteria for economical, high-power and efficient combustion and meet environmental regulatory standards. One method that has a lot of interest is changing the characteristics of the fuel, with the aim of producing optimal combustion. Spray characteristics have a big role in determining the quality of combustion in diesel engines. A good spray can improve the quality of fuel atomization and the homogeneity of the air-fuel mixture in the combustion chamber so that it can produce good engine performance and low emissions. This study aims to determine the effect of a diesel-biodiesel (*Calophyllum inophyllum*)-gasoline blend and fuel heating on the spray characteristics. The research was conducted with variations in composition (B0, B100, B30, B30G5 and B30G10) and fuel heating (40, 60, 80, and 100 °C). Fuel injected at a pressure of 17 MPa in to a pressure chamber of 3 bar. The spray formed was recorded with a high-speed camera of 480 fps (resolution 224x168 pixel). In B100 biodiesel, the highest viscosity and density cause high spray tip penetration, small spray angle, and high spray velocity. The addition of diesel oil, gasoline, and heating fuel reduces the viscosity and density so that the spray tip penetration decreases, the spray angle increases and the velocity of spray decreases.

Keywords: *Biodiesel blend, gasoline and preheating fuel, spray characteristics*

I. Introduction

Technological developments in diesel engines require improvements to the fuel injection system to meet the criteria for economical, high-power and efficient combustion and meet environmental regulatory standards [1]. Viscosity has a major role in changing the characteristics of the spray. The research relationship between properties of physical liquid fuels and characteristics of the spray revealed that the characteristics of the spray are affected by the physical properties of liquid fuels [2-3]. Spray characteristics with fuel nonconventional have different microstructures of conventional fuels, such as length of spray, spray angle, and spray speed that produces quality mixing of air and fuel [1].

As one alternative fuel, *Calophyllum inophyllum*a source of raw materials potential, contain oil that is high and can grow well in the tropics [4-6]. *Calophyllum inophyllum* biodiesel has good oxidation stability [7], so it is classified as a high-quality fuel with stable combustion characteristics and is safe for transportation with a relatively high flash point and acidity [8]. But biodiesel fuel is identical with chemical properties that are non-volatile, more viscous, relatively large droplets, resulting in poor atomization [9].

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Vol. 5, No. 2, November 2021, pp. 135-144

Some of the solutions of which is the addition of gasoline and preheating fuel [10] in their research adding fuel and kerosene to biodiesel waste cooking oil, resulted in a decrease in density, cetane number and viscosity properties. Examined the fumigation gasoline on fuel diesel oil and B20 [11], produced in a significant improvement in lowering emissions of UHC, exhaust gas temperature, smoke opacity, emissions of NO_x and CO_2. Fuel heating up to 100°C does not have an adverse effect on the injection system [12].

Preheating temperature of biodiesel effectively lowers kinematic viscosity, density and surface tension, wherein the physical properties of these fuels have a major impact on the process of atomization in the combustion chamber [13-14]. Increased preheating temperatures of fuel affect spray tip penetration and spray angle, similar thing happened in the spray area and volume spray [15]. As for engine performance and emissions, heating of biodiesel and its blend can improve engine performance, reducing CO emissions, although there is still an increase in NO_x emissions due to higher combustion temperature[13], [16-17].

It is necessary to further research the characteristics of the spray on diesel-biodiesel and gasoline fuel blend with preheating temperature. The study aims to determine the effect of the fuel blend and preheating temperature on the spray characteristics, including spray tip penetration, spray angle and velocity of spray.

II. Material and Methods

The fuel used in this study is a diesel (produced by PT Pertamina Indonesia), biodiesel made from *Calophyllum inophyllum* seed oil obtained from Bondowoso, East Java, Indonesia. *Calophyllum inophyllum*extracted mechanically, followed by esterification and transesterification of *Calophyllum inophyllum* oil triglycerides and gasoline (premium produced by PT Pertamina Indonesia with an octane number 88). The composition of the fuel blend is shown in Table 1.

Table 1. Composition of diesel-biodiesel-gasoline fuel blend

No	Mixture Code	Diesel	Biodiesel	Gasoline
1.	B0	100 %	0 %	0 %
2.	B30	70 %	30 %	0 %
3.	B30G5	95%B30		5 %
4.	B30G10	90% B30		10 %
5.	B100	0 %	100 %	0 %

Mixing of the fuel use the dissolving method [18], which is conducted with a stirrer process for 10 minutes using magnetic stirrer (50-1000 rpm, max 2.5 liter, 25-110ºC) at a certain room temperature condition (40ºC) and a speed of 350 rpm constantly. That fuel is heated with variations temperature of 60°C, 80°C, and 100°C before being injected on test equipment. The testing process is conducted in 2 stages, testing the fuel propertiesby using pycnometer for density and viscometer Ostwald for viscosity, then testing the spray on the nozzle tester. Spray test using an injection pressure of 17 MPa with type nozzle R175 single hole and spray chamber at a pressure of 3 bar. This chamber has 2 transparent sides made of acrylic glass. One side is used to record the spray that occurs, and the other side is for lighting. The condition of the tester nozzles is shown in Table 2.

Vol. 5, No. 2, November 2021, pp. 135-144

The spray was recorded using a high-speed camera of 480 fps (frame per speed) with a resolution of 224x168 pixel. Lighting use halogen lamps 1000 Watts. The test scheme is shown in Figure 1.

Table 2. Experimental conditions

Fuel	B0, B100, B30, B30G5, B30G10
Temperatur Fuel	60, 80, 100
Injectors and injection conditions Injector type Number of nozzle holes Nozzle diameter	 R175 type 1 0.8 mm
Injection Pressure Ambient Pressure	17 Mpa 3 bar
ChamberDimensions Thick iron plate Thick acrylic glass	Length x width x height = 30 x 30 x 30 cm 10 mm 10 mm

The results of the spray in the form of video are converted into images which are then measured the spray tip penetration and the spray angle in each image.

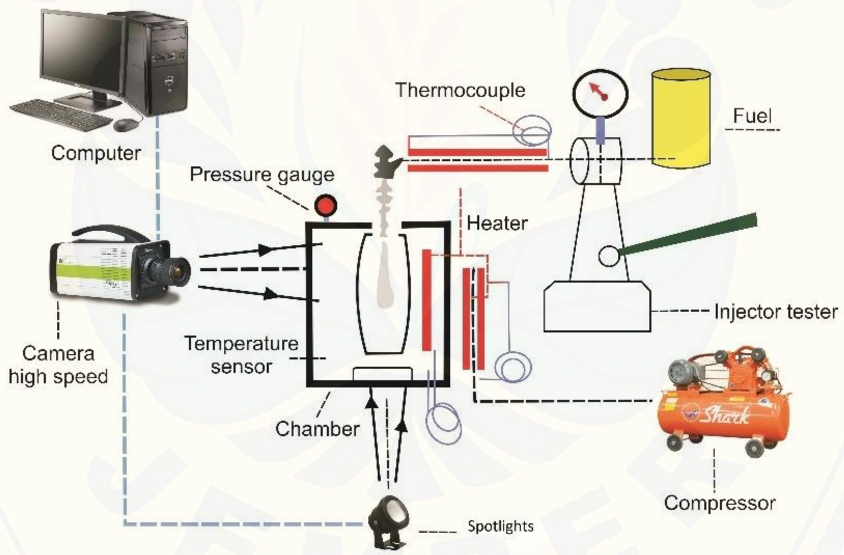

Fig.1. Test schemeof spray characteristics

III. Result&Discussion

A. Fuel Properties

Fuel blend in the test characteristics and the results of its indicated on Tabel 3. In this table, it appears that all of the fuel mix used has properties in accordance with standard fuel (diesel-B0). From the table, we also know that the higher the percentage of the gasoline mixture, the lower the density and viscosity of the fuel blend. Peak combustion pressures of biodiesel/gasoline blend fuels increases lightly [19]. While ignition delays, peak heat release and thermal efficiency decrease but specific consumption increase [10].

Vol. 5, No. 2, November 2021, pp. 135-144

Table 3. Fuel blend characteristics

Composition of fuel blend	Density 40° (gr/mL)	Viscosity 40° (Cst)
B0	0.811	2.120
B30	0.828	2.842
B30G5	0.818	2.397
B30G10	0.798	2.219
B100	0.836	3.080

Table 4 are shown the viscosity of the fuel blend and preheating temperature. From this table, it can be seen that the viscosity of the tested fuel decreased with increasing fuel temperature. Fuel preheating cause hydrocarbon and carbon monoxide emissions increase at partial and medium loads and drop at high loads [20].

Table 4. Characteristics of fuel viscosity with preheating temperature

Fuel Temperature (°C)	Viscosity (Cst)				
	B0	B100	B30	B30G5	B30G10
60	1.897	2.978	2.777	2.342	2.013
80	1.642	2.933	2.623	2.269	1.961
100	1.498	2.865	2.359	2.190	1.903

B. Spray Tip Penetration

Spray characteristics of the fuel blend in this study and preheating temperature of fuel are shown in Figure 2, that is taken in the second spray or at the time 4.16 ms. Each spray length is measured, and the results are displayed in graphical form so that it is easy to observe, and the measurement results are shown in Figure 2.

Figure 3 shows the results of measuring the spray tip penetration of the fuel blend with fuel heating. The figure shows that 100% biodiesel (B100) has the longest spray tip penetration for all fuel temperature variations. This is caused by B100 having the viscosity and density of the highest that causes the spray easily through the air in the chamber so long spray tip penetration. The addition of 5% - 10% gasoline (B30G5- B30G10) and the addition of 30% diesel (B30) causes the viscosity and density to decrease so that the spray tip penetration also decreases but spray tip penetration of B30G10 is closest to B0. The addition of diesel also lowers the viscosity and density of the fuel blend, so that spray tip penetration is also declining. The diesel oil fuel 100% (B0) as the standard is commonly used in Indonesia so that the viscosity and density are the lowest, which causes the spray tip penetration to be the lowest. While the increase in the percentage of gasoline in the fuel blend is able to reduce the density value of fuel blend [21].

The preheating temperature of the fuel also reduces the spray tip penetration of all fuel compositions because heating the fuel causes the viscosity and density to decrease as well. The lower viscosity value fuels reduce the grain size of spray so that the ability of the spray to pass through the air pressure in the chamber decreases [22]. This is because as the density of the fuel increases, the mass of the flow rate increases and causes the momentum to increase which allows the spray to move more easily [23-24]. Increasing the percentage value of the biodiesel blend increased the viscosity and density values but increasing the heating temperature of the fuel could decrease it [25]. The effect of preheating of fuel on viscosity can reduce spray tip penetration [15].

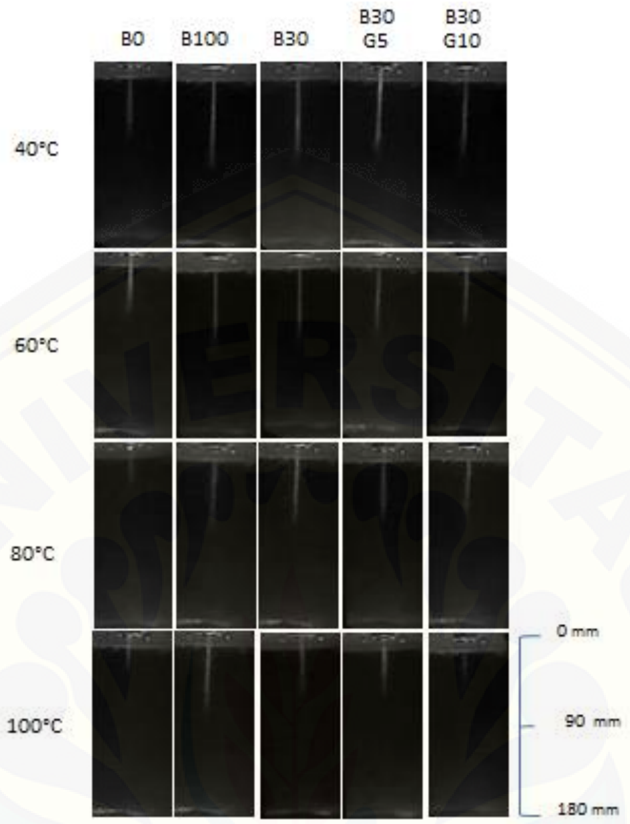

Fig. 2. Spray at different fuel blend and preheating temperature
at the time 4.16 ms (second spray)

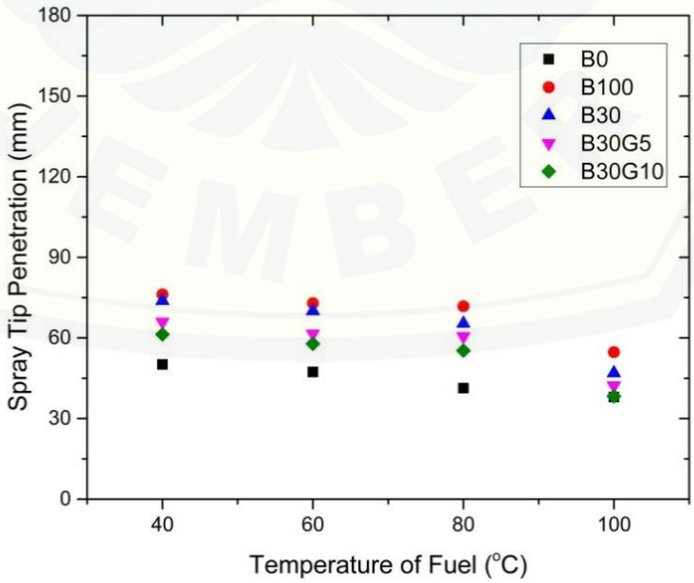

Fig. 3. Spray tip penetration at different fuel blend and preheating temperature
at the time 4.16 ms (second spray)

C. Spray Angle

The spray angle of the fuel blend in this study with preheating temperature is shown in Figure 4, which is taken in the third spray or at a time 6.24 ms. Each spray angle is measured, and the results are displayed in graphical form so that it is easy to observe, and the measurement results are shown in Figure 5.

Figure 5 is the average spray angle on the variation of the fuel blend and preheating temperature. In the figure, it can be seen that biodiesel fuel (B100) has the smallest spray angle. This is because B100 has the highest viscosity. The high viscosity and density of biodiesel cause poor atomization results [26], which causes deep penetration of the spray into the air in the chamber and large fuel momentum.

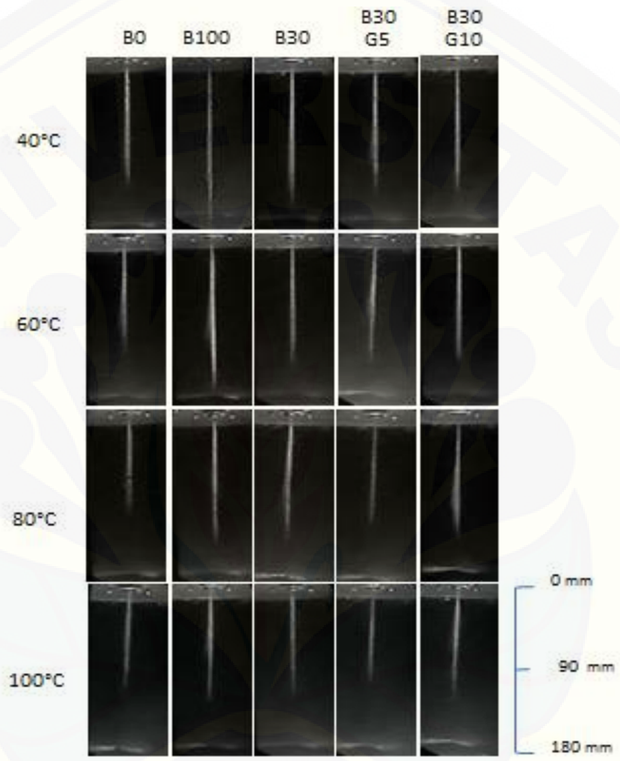

Fig. 4. Spray at different fuel blend and preheating temperature at the time 6.24 ms (thirdspray)

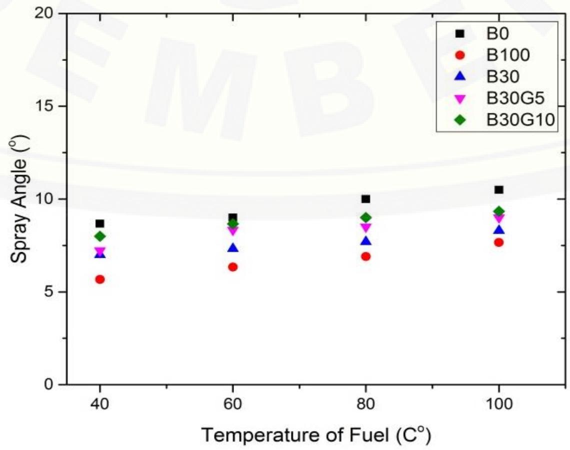

Fig. 5. Spray angle at different fuel blend and preheating temperature at the time 6.24 ms (third spray)

D. Velocity fo Spray

Velocity of spray with variations in fuel blend and preheating temperature is shown in Figure 6 that taken at the third spray or at the time 6.24 ms. The effect of fuel blend composition shows that biodiesel fuel (B100) has the highest velocity of spray. The addition of diesel oil and gasoline reduces the velocity of spray due to its viscosity and density change.

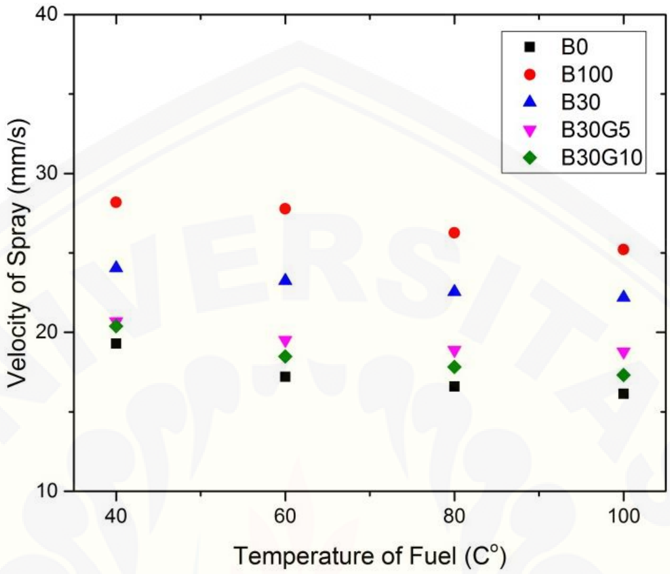

Fig. 6. Velocity of spray at different fuel blend and preheating temperature at the time 6.24 ms (third spray)

The fuel heating also reduces the properties of the fuel so that it affects the velocity of spray, where the lowest spray occurs at the highest heating of 100 C, and the highest spray occurs at a temperature of 40°C. The decrease of velocity of spray affects the decrease in the momentum of the fuel to the air so that the homogeneity of the air and fuel blend decreases[21], [23-24]. Spray tip penetrations are almost the same as each other, meaning that the velocity of spray and the momentum of the fuel are the same [30]. It needs a combination of treatment between the chamber condition and fuel composition so that the momentum, spray angle, and spray tip penetration remain high so that the homogeneity of the fuel and air mixture could be better.

IV. Conclusions

Research has been carried out on the effect of adding gasoline and heating fuel, and the results are the additions gasoline to the diesel and biodiesel fuel blend decrease spray tip penetration, increase spray angle, and decrease velocity of spray and preheating temperature of fuel causes a decrease in the viscosity and density of the fuel blend, which affects the spray characteristics.

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