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EFFECT OF MIXTURE FORMATION ON COMBUSTION IN BURNER SYSTEM

Mirnah Suardi[1], S. H. Amirnordin[1] and Amir Khalid[2]
[1]Combustion Research Group, Centre for Energy and Industrial Environment Studies, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia
[2]Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia
E-Mail: mirnahsuardi@yahoo.com

ABSTRACT

The energy and natural resources being increase due to the growth economic and attention together with the alternative fuel. As one of different solution to these problems, emulsion fuel technology in biodiesel has received close attention because it may provide better combustion efficiency and would contribute to a reduction in emissions, such as nitrogen oxides (NO_x) or particulate matter (PM). This solution of this issue is by using biodiesel fuel as an alternative fuel from Crude Palm Oil (CPO). CPO is one of the most economical options for producing biodiesel due to the biodegradable properties and preserves energy. This study focuses on the observation of ignition and combustion characteristics of biodiesel-water-air rapid mixing of biodegradable fuel using internally rapid mixing injector in burner combustion. In these experiments, biodiesel fuel derived from the crude palm oil were used in the same nozzle $\theta = 50°$ characteristics of burner system. This study focuses on the observation of the real images of the spray characteristics together with equivalence ratio, water content, spray penetration length, spray angle and spray area. Water emulsion of percentage up to 15vol% and blending of biodiesel ratio was varied from 5vol%- 15vol%. The diesel fuel has been compared with based analyzed of real spray images with the times change. The results show the percentage of biodiesel and shows the higher of water content due to the higher viscosity affects.

Keywords: alternative fuel, crude palm oil, rapid mixing, mixture formation, flame, emissions.

INTRODUCTION

Renewable fuels such as biodiesel continues to be of interest to achieve a sustainable energy economy, thus reducing dependence on fossil fuels. It is noted that the use of transportation fuels that are renewable and its use is increasing, particularly in Malaysia.

In Malaysia, the development of biodiesel is increase in particularly for Crude palm oil (CPO). CPO is readily available, safe to store and handle, and most importantly, totally renewable. Its negligible sulphur content compared with diesel's reduces the possibility of acid rain caused by sulphur dioxide emissions [6].

Environmental concerns and the rising cost of fossil fuels such as diesel resulting in research on alternative fuels such as biodiesel have a charm of its own. Biodiesel is an environmentally friendly fuel that is clean and is a source of energy that can be renewed. It is usually made from animal fat or vegetable oil revenue trans-esterification reaction. The oxygen content in biodiesel is 11% - 15%, increased combustion process and reduces emissions from diesel engines [1]. The use of biodiesel is very good because it can help reduce the emission of harmful gases such as sulphur dioxide (S), carbon monoxide (CO) and hydrocarbons (HC). However, the percent of nitrogen oxide emissions (N) are very high compared to diesel fuel. This is because nitrogen oxide (N) is closely related to the concentration of oxygen in biodiesel fuel. In terms of the combustion process, the biodiesel is able to produce a complete combustion process compared to diesel fuel [2] [4].

This research analyze the effect of mixture formation, crude palm oil blended fuel, injector on the burner system.

Rapid premixing in the combustion process is used to reduce the gas emission especially NO_x and flame temperature. The premixing also influenced on flame propagation phenomena. As additional, the gas emission also can be reduce by controlling the spray characteristic such as spray penetration and spray angle to compare fuel diesel and biodiesel Crude Palm Oil (CPO).

EXPERIMENTAL SETUP

The biodiesel used to be CPO biodiesel, which blended from Universiti Tun Hussein Onn Malaysia (UTHM) Automotive Laboratory and the particular of the tested fuel are detailed in Table-1. The CPO biodiesel blended with diesel in various concentrations for preparing a biodiesel blend. Biodiesel blend starts from B5 to B15 using the blending machine. During blending process, the mixture was stirred at 70^0C for 1 hour and the rotating blade speed was adjusted to maintain the speed at 270 RPM. The injector is equipped with one air compressor and two electrical pumps. Air flow rates and fuel flow rates are controlled by control valve and a voltage regulator respectively.

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Table-1. Properties of biodiesel fuel.

Fuel Type	Properties			
	Density (g/cm^3)	Kinematic Viscosity (cP)	Flashpoint (°C)	Water Content (ppm)
STD	0.833736	3	80	79.6
B5	0.837048	3	91.5	120.1
B10	0.837664	2.9	92	158.6
B15	0.840428	3	93.5	219
B20	0.841172	3.1	94.5	294.7
B25	0.841716	3	97	363.3
B30	0.845852	3.2	97.5	397.1
B35	0.844816	3.4	99.5	426.9
B40	0.848236	3.2	100	558

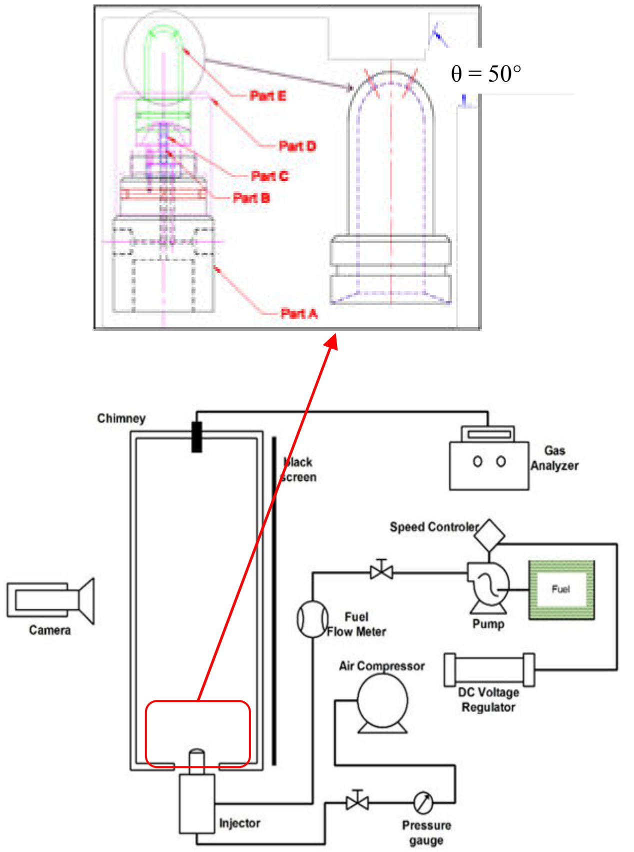

Figure-1. Schematic diagram of biodiesel burner.

A schematic diagram for this experiment are shwon as in Figure-1. Investigate the spray characteristics and flame propagation. Air compressor and pump selection is the important thing to achieve the objective for this project. The Atomizing air with pressure 0.25bar will be supplied by the air compressor. The function of air compressor is to suck air from atmosphere then compress air to high pressure. Specifications of this compressor are summerize in Table 2. Fuel is initially rapidly mixed with fuel-water-air will then pumped by the fuel pump to inject; afterwards the injector sprays the mixtures out with very fine droplets [1-3] [9].

Table-2. Experimental condition.

Air Compressor	Model	QUASA HDC-D3050
	Capacity, L/min	200
	Pressure, kg/cm^2	8
WaterPump	Model	SFDP1-014-080-22 – Seaflo
	Voltage, V	12
	Flow rate, L/min	5.1
Fuel Pump	Model	CNY-3805
	Pressure, bar	3
	Flow rate, L/Hr	100
DC Voltage Regulator	Model	Teletron TC-1206A
	Current, A	64 (max)
Operating condition	Air Pressure, bar	0.25
	Air Density, kg/m^3	1.16
	Ambient Temperature, K	300
	Water Percentage	0-15%
	Equivalence ratio	0.6-1.4

This project has two pumps and locates at water fuel tank. Pump number 1 is fuel pump for supply fuel to injector and pump number 2 is water pump for continuous water. Fuel-water go through to the mixing chamber and mix with air (pressure 0.25 bar) then sprays out the mixtures to atmosphere. Air flow rates is control by voltage regulator and monitor by meter flow meter.

Two separate experiments were conducted at atmospheric condition to analyze the effect of fuel-water-air: 1) capture spray image and 2) capture flame image. The flame was igniting by brazing torch kit.

The camera aperture was set to f5.6, the shutter speed is at 1/80 Sec for the spray image. The spray characteristic which includes penetration length and spray angle is an analysis, only one hole from the nozzle will be analyzed. Few set of spray image which from different flow rates and water content being taken to be compared. This study is keeping the injection air pressure at 0.35 bar and ambient density of 300K, all the operating condition and equipment specification are summarized in Table-2.

RESULT AND DISCUSSIONS

The Table-3 indicates the spray development of CPO5 biodiesel. The time sequences, equivalence ratio, pressures and water content added is same as the spray experiment for nozzle angle 50°.

From the table, volume of spray increases with time and it is drawn by the ventilation system. The spray image becomes clearer and wider at high equivalent ratio. This means that there is more fuel is being injected to the injector. The penetration length shows an increasing trend with equivalence ratio for each type of water content.

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Table-3. CPO5 spray development for 50° of nozzle.

Fuel	Water Content	Equivalent Ratio	Time Sequence (s) 0	0.03	0.06	0.09	0.12
Crude Palm Oil (CPO B5)	W0	0.6					
		1.0					
		1.4					
	W5	0.6					
		1.0					
		1.4					
	W10	0.6					
		1.0					
		1.4					
	W15	0.6					
		1.0					
		1.4					

Spray characteristics. Based on the Figure-2, penetration length, spray angle and spray area against equivalence ratio of different fuel is plotted. Penetration length for each type of fuel is increasing with the equivalence ratio.

For the penetration length, increase of the equivalence ratio enhanced the penetration length. CPO15 has the longest penetration length which is 315.86mm. The penetration length of blended CPO is higher than the diesel. This explains the relationship between the penetration length and the viscosity of the mixture. Since the viscosity of biodiesel is higher than diesel, longer penetration length will produce.

Furthermore, trend of spray angle shows that the angle is decreasing as the equivalence ratio is increasing. From the graph it is found that diesel has the highest spray angle followed by CPO 5, 10 and 15 which are 7.1°, 6.92°, 6.34° and 6.32° respectively. This behavior associated with the viscosity is lowest for diesel. It can say that the spray angle is inversely proportional to the viscosity of the mixture.

Next, a similar trend is observed in spray area with penetration length. Penetration length gives more significant effect on the spray area. CPO15 produced largest spray area and the smallest area for diesel. This seems that the increase of the penetration length causes the spray area increase where the spray area for CPO15 is smallest.

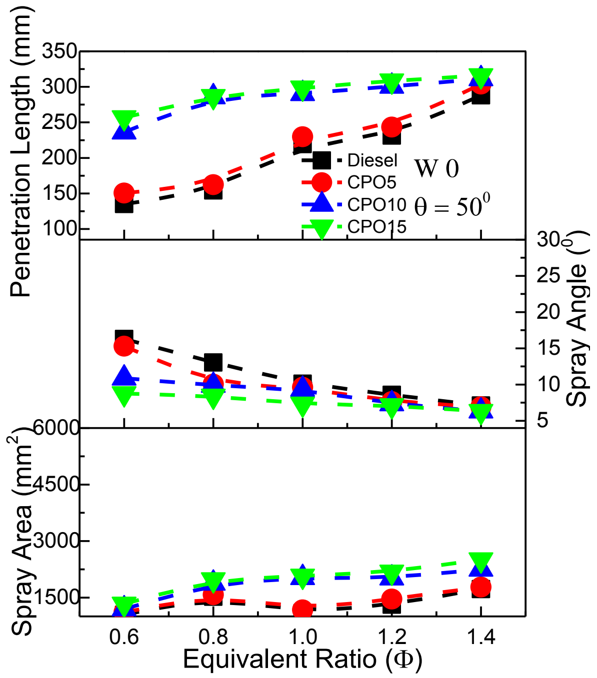


Figure-2. Spray characteristics of different fuels at W0.

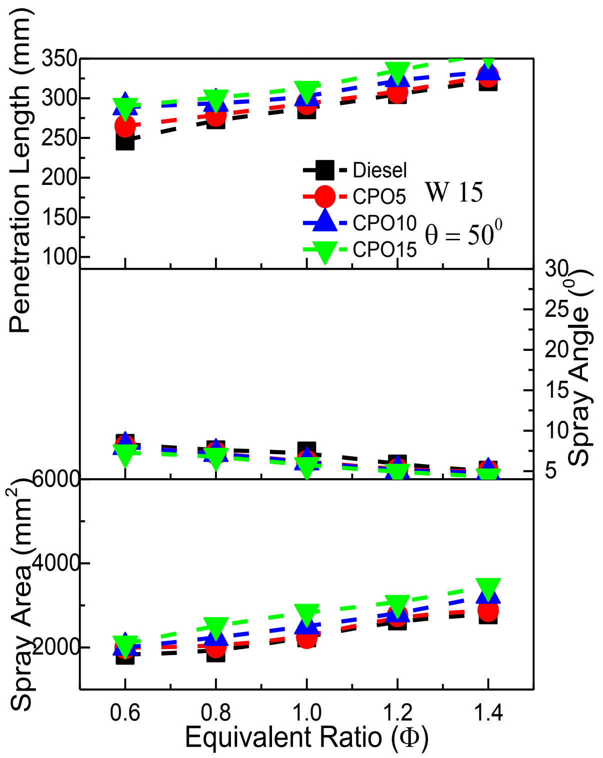


Figure-3. Spray characteristics of different fuels at W15.

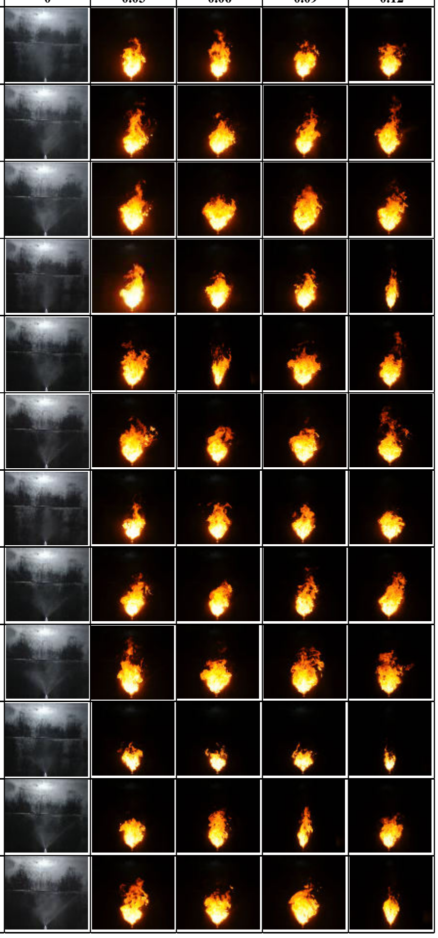
Figure-3 shows the spray characteristic of the different fuel at W15. The penetration length of the fuel has same trend with the Figure-2. CPO15 has longest penetration length with 356.28mm and diesel has the shortest length which is 246.98mm. Observation of spray

ARPN Journal of Engineering and Applied Sciences

angle is decreasing with an equivalence ratio of 0.6 to 1.4. W15 has the smallest spray angle compared to the others since it is more water was injected into the fuel and increase the viscosity as well. Diesel has the highest spray angle which is 5.02° followed by CPO5, 10 and 15 with 4.92°, 4.8° and 4.32° respectively. For the spray area, same trend has shown and the spray area is increasing based on fuel of high to low viscosity. Diesel trend has shown with the acceptable trend which is low compared to other fuels. This means that the previous problems had been solved with effective solutions.

Table-4. CPO 5 flame development for 50° of nozzle.

Fuel	Water Content (%)	Equivalent Ratio	Time Sequence (s) 0	0.03	0.06	0.09	0.12
CPO5	W0	0.6					
		1.0					
		1.4					
	W5	0.6					
		1.0					
		1.4					
	W10	0.6					
		1.0					
		1.4					
	W15	0.6					
		1.0					
		1.4					



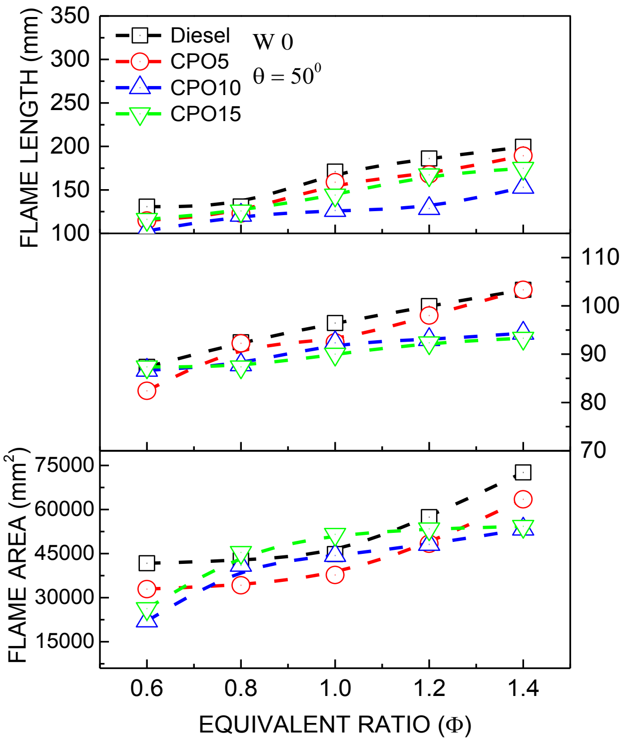


Figure-4. Flame characteristics of different fuels at W0.

Flame propagation. Based on the graph Figure-4, flame length, total flame angle and flame area against equivalence ratio of different fuel is plotted. Flame length for each type of fuel is increasing with the equivalent ratio. Maximum flame length occurred at diesel among the other fuel which is 199.60mm and CPO10 has the shortest length which is 102.82mm. This explains the proportionality between the flame length and the viscosity of the mixture, which is same situation with the 45°of nozzle.

Moreover, the total flame angle for each type of fuel with increase of equivalent ratio which are from the diesel followed by CPO5, 10 and 15 at equivalent ratio of 1.4 which are 103.32 °,102.42°,94.33°and 93.30 °. This shows that as the viscosity of the fuel increases, smaller spray angle will be produces. Same situation happened with the spray area compared to the 45° of nozzle.

From the Figure-4. 18, the diesel shows the longest flame length which is 167.45mm where the smallest flame length is CPO15 which is 110.82mm. Total flame angle shows uniform trend which fuel with high contents of diesel produces larger total flame angle followed by CPO5, 10 and 15 receptively which is 100.05°,96.85°, 96.85°, 96.46°and 92.51°.

Flame area also shows uniform trend, the flame area with all fuels increases uniformly to highest at equivalence ratio of 1.4.

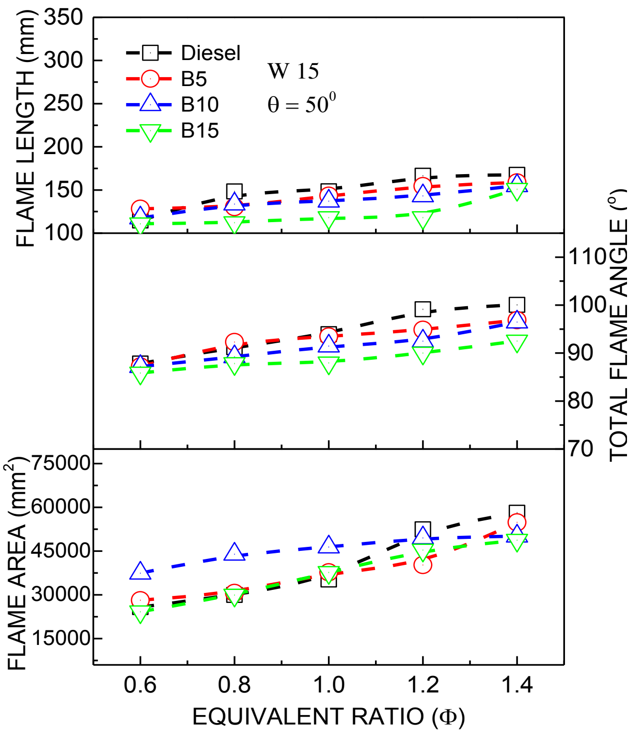


Figure-5. Flame characteristics of different fuels at W15.

CONCLUSIONS

In this research, a fundamental study on the mixture formation of rapid mixing of biodiesel-water-air technique was carried out using a burner system. It has been changing water content and the equivalent ratio. High water content in the mixtures will result in longer penetration length and smaller spray angle. Penetration length is contributing in spray area, where longer the length will produce the larger area. An equivalent ratio will give effect increase the penetration length as the equivalent ratio increase. In addition, flow rate makes the color intensity of spray increases with the increment of equivalence ratio, more fuel is being injected and hence the concentration of diesel fuel in the mixtures increases.

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