Spray Characteristic of Rapid Mixing Jatropha Oil Biodiesel in Burner System

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Keywords: Burner, Premix Injector, Crude Jatropha Oil, Diesel Combustion, Spray Development, Spray Characteristics, Flame Development.

Abstract Jatropha Oil (JPO) is an alternative fuel proposed to be used especially for renewable sources and energy preservation. Its characteristics need further investigation particularly for the use in burner combustion. The purpose of this research is to investigate the effects of mixture formation and micro-explosion phenomenon during the rapid mixing of biodiesel-water and combustion process in burner combustion. In this research, the observation of mixture formation under variant blending ratio Jatropha oil biodiesel and premixing injector were focused on spray characteristics, mixture formation, flame development and exhaust emissions. The Jatropha oil was blended with standard diesel under different ratio; JPO5, JPO10, and JPO15 and variant in water content of W0, W5, W10 and W15. Real images captured using direct photography method were analyzed in order to understand the spray angle, spray penetration length and spray area under different equivalent ratio and water content. Addition of water content associated with the changes of the fuel-air mixture formation, hence it influences to the spray penetration length, sprays area and thus predominantly influences to toxic emission during combustion process.

Introduction

Despite of being the alternative to the fossil fuel, biodiesel is one of the preferred fuel choices since it decreases the effect of acid rain and greenhouse by reducing the emission of CO_2, SOx and unburned hydrocarbons during combustion [1-3]. Besides, biodiesel sources are renewable and they offer enormous opportunity in bio-based economy market [4-5]. Jatropha Oil (JPO) is a renewable fuel proposed to be used instead of other biodiesel fuel due to the suitability to be used as alternative diesel and meet the current European EN 14214 and US ASTM D6751-02 biodiesel standards. Jatropha and karanja oils are reportedly more suitable to be used in cold weather[6-8]. Another problem is the increase in exhaust toxic emissions such as NOx, CO and particulate matters (PM) during burning process that cause environmental problem. Diesel-water emulsion is the simpler and cheapest way to reduce the emission of combustion and associated with the adoption of the diesel-water emulsified. During this phenomenon, the heat absorption by water vaporization causes a decrease of local adiabatic flame temperature thus decreases the NO_x emissions [7]. The fuel is vaporized to a small particular after the explosion of water droplets, this is named as micro-explosion phenomenon that occurs during the mixing of water and fuel, and it's made up of two or more liquids with relatively large differences between their boiling temperatures. Heat absorption by water vaporization causes a decrease of local adiabatic flame temperature and reduction of peak flame temperature that associated with lower the PM emissions and produces less toxic emission[8-9]. Thus, this research introduced the rapid premixing nozzle in order to reduce the exhaust emissions production through controlling the combustion process. This technology used water-fuel-air premixing in nozzle chamber together with fuel injection system will provide numerous benefits to the consumers as well to the environment. The important fuel properties of crude Jatropha oil and biodiesel are shown in Table 1. Fuel-air mixing prior to combustion process is an important phenomenon in the burner combustion. In this process, fuel will be mixed together to complete the combustion air.

Table 1: Fuel properties of Jatropha oil and their biodiesel in comparison with diesel [4]

Properties	Crude Jatropha oil	Jatropha biodiesel	Diesel
Viscosity (mm^2/s)	35.4	4.59	4.84
Flash point (^oC)	226	182	71
Fire point (^oC)	236	190	76
Gross calorific value ($MJ\ kg^{-1}$)	39.76	45.2	46.22
Density ($g\ ml^{-1}$)	0.94	0.88	0.83

In this study, the experiments focused on the characteristics of the injector nozzle which influences the spray angle, spray penetration, fuel formation and gas emissions. The use of fuel injector on a diesel burner system is an effective method for controlling the fuel consumption and spray characteristics during combustion process.

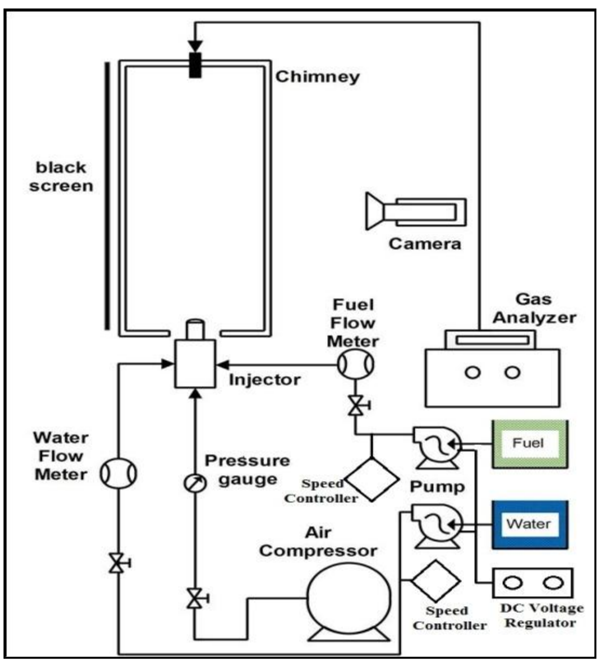

Figure 1: Schematic diagram of experimental setup

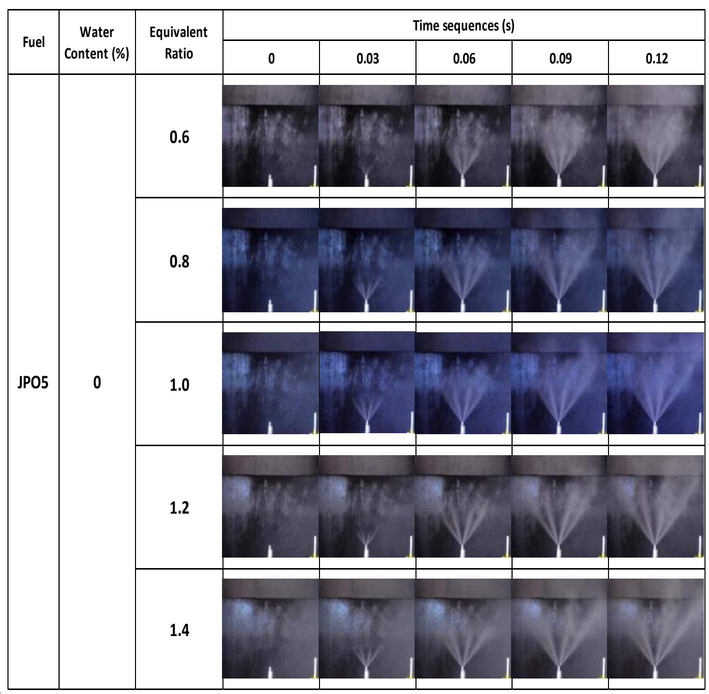

Figure 2:JPO5 biodiesel spray development (W0)

Experimental Set up

Blending is the process of mixing of crude Jatropha oil and diesel. In this experiment a mixture of Jatropha oil and diesel in particular quantities will produce a biodiesel blend. During the blending process, the biodiesel will be stirred continuously for one hour to produce a homogeneous mixture. The temperature for the blend diesel and biodiesel must be reached 70^{o}C.The rotating blade speed was adjusted to maintain the same speed at 270 rpm. The JPO5, JPO10 and JPO15 biodiesel show the rate of blend biodiesel diesel. JPO5 biodiesel means a blend of 5vol% biodiesel and 95vol% diesel and subsequent identical to JPO10 and JPO15. Figure 1 shows the schematic diagram of burner system including the fuel system and burner injector. Air flow rates and fuel flow rates are controlled by control valve and voltage regulator respectively. At the initial process of experiment, the mixture of diesel and water is mixing inside the chamber where mixtures are recirculating continuously by the washer pump. Then, by controlling the DC voltage regulator, the mixtures of diesel and water are able to pump into the injector by using fuel pump. After the diesel-water mixtures mixing with air inside the mixing chamber, the mixtures are spray out from the nozzle. The real images of mixture formation are captured by using Digital Single-Lens Reflex (DSLR) camera. The experiment is repeated for different equivalent ratio with biodiesel JPO5, JPO10 and JPO15 for water content W0, W5, W10 and W15 respectively.

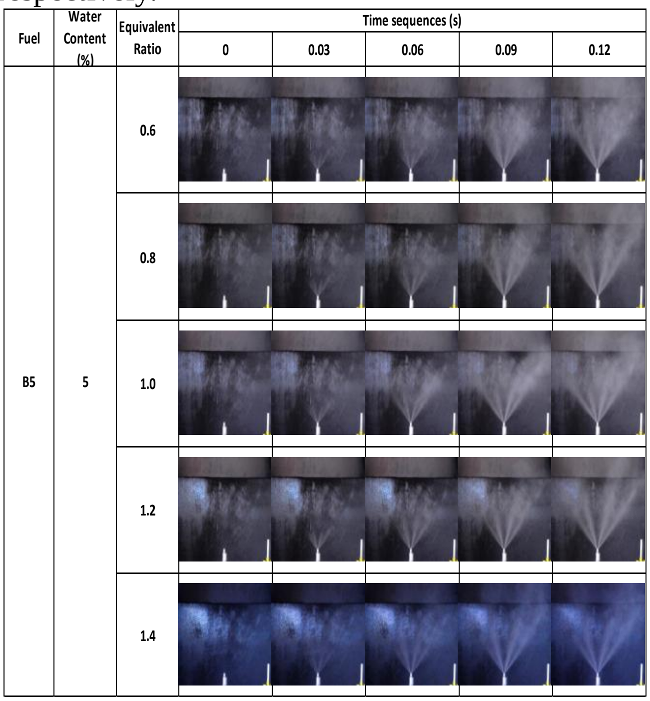

Figure 3: JPO5 biodiesel spray development (W5)

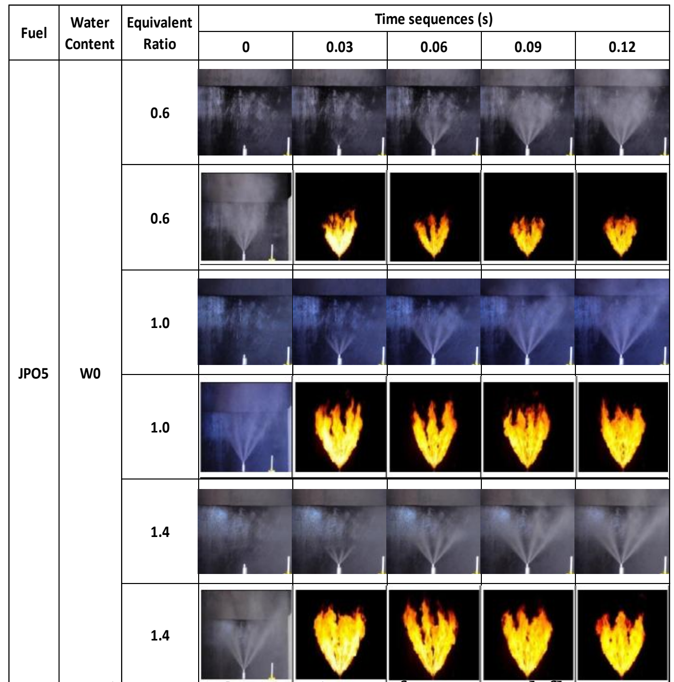

Figure 4: Comparison of spray and flame development for JPO5 at W0.

Result and Discussion

An effect of the diesel and JPO biodiesel fuel with eight holes nozzle on mixture formation was firstly investigated. The angle for the hole of type injector nozzle that used in this experiment is $\Theta=45°$. Figure 2 and 3 shows the spray development of water content W0 and W5 for JPO. The formation of spray pattern start from time 0.00 second until 0.12 second, time sequence is referring from start of injection. The interval between each image taken is 0.03 second for every set of different equivalent ratio and water content. The spray of biodiesel fuel is spraying upward from the injector when the supply mixtures are pump into the injector, as vary with time, the volume of spray increases at 0.12 second after start of injection. Under high equivalent ratio, the spray image becomes clearer due to the increment of the flow rate of the mixtures. This indicates that more fuel is being injected into the injector and the spray contains more fuel particle compared to the spray of low equivalent ratio. As observed from the images, the spray is starting to expand at time 0.06 second for all types of water content and equivalent ratio, thus it can be seen that after time 0.06 second after start of injection the overall diesel spray is become thicker.

Next, the influences of the water-emulsified on ignition point and flame development were investigated. Figure 4 shows the flame developments of diesel with different equivalent ratio and JPO5 fuel. Under lower equivalent ratio, the flame area is low bright and its flame height is lower than high equivalent of JPO5 fuels. In diesel and biodiesel, the flame is formed when there is enough of air-fuel ratio in combustion. The difference of flame image between pure fuel and water mix with fuel is the color of flame. It can be seen that water mix with fuel has brighter color and shorter flame than 100% pure fuel.

Figure 5,6,7 and 8 show the mixture formation against equivalent ratio for four different kinds of fuel of diesel, JPO, JPO10 and JPO15 at water content of W0, W5, W10 and W15. Spray angle can be defined as two straight lines from the nozzle tip then forms the largest angle at the boundary of the spray. In this experiment, it is found that JPO10 spray angle is greater than JPO5, JPO15 and diesel at all water content. However, for W5 water content, diesel has the higher spray angle compared to other fuels. The second spray characteristics studied in this experiment is spray area for selected hole from injector nozzle.

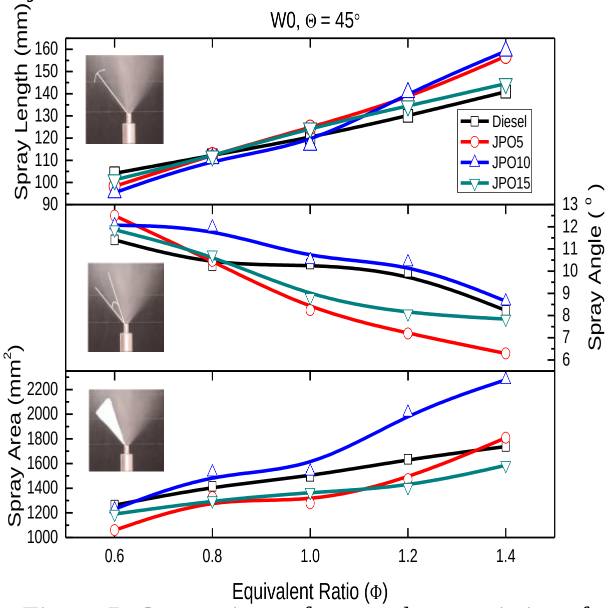

Figure 5: Comparison of spray characteristics of fuels at W0.

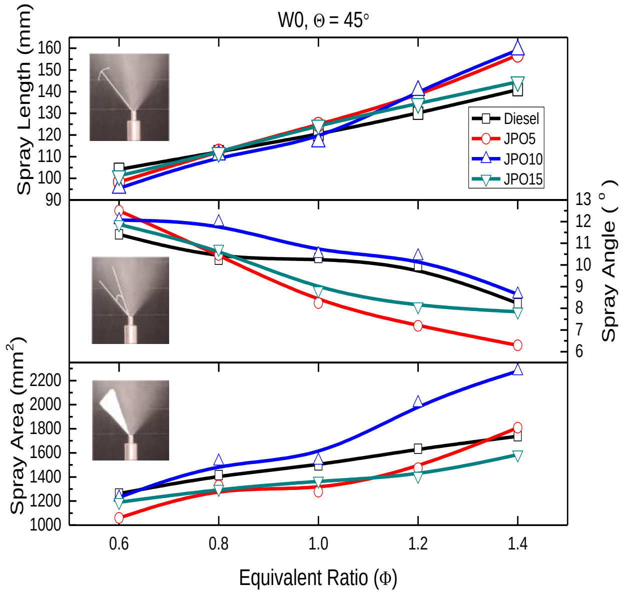

Figure 6: Comparison of spray characteristics of fuels at W5.

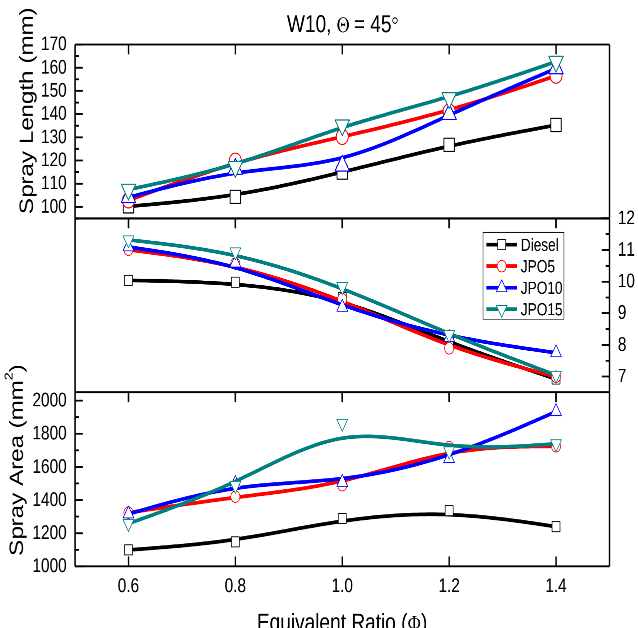

Figure 7: Comparison of spray characteristics of fuels at W10

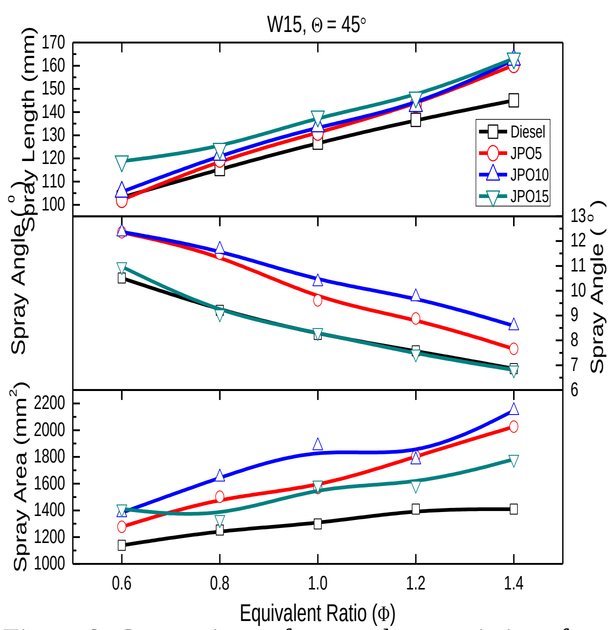

Figure 8: Comparison of spray characteristics of fuels at W15

The spray area depends on the spray angle and spray penetration. Hence, it is also influenced by the properties of the fuel. From the experimental results, it is discovered that spray area for JPO10 biodiesel has the largest spray area compared to other fuels. Spray penetration also depends on the properties of the fuel. Results show that the use of biodiesel JPO5 produce the longest penetration length compared to other fuels at water content of W5, W10, and W15. As a result, it can be seen that diesel produce the shortest penetration at water content W5, W10 and W15.

Conclusion

The experiment conducted with premix injector in external burner system and used different biodiesel blending of Jatropha JPO5 (5vol% jatropha oil), JPO10 (10vol%) and JPO15 (15vol%). A comparison of spray characteristics was made between standard diesel and different biodiesel ratio: JPO5, JPO10 and JPO15 and water content variant in W0, W5, W10 and W15. Results are summarized as follows;

1. JPO biodiesel has longer penetration length and larger spray area compared to diesel. Increased of flow rate makes the color intensity of spray increase which indicates that more fuel is being injected and hence the concentration of diesel fuel in the mixtures increases. This phenomenon associated with the increasing of water content will tends to increase the kinematic viscosity of the fuel, thus kinematic viscosity increase will make the resistance strength and surface tension of the fuel become higher.
2. Flame length of the combustion for pure diesel is longer than those diesel mixed with water, whereas, larger flame area is produced by higher equivalent ratio which the spray contains more fuel particles that makes the combustion process easy to takes place. Therefore, the increased of water content can reduce the flame temperature and soot emission, due to the effects of oxygen content in water.

Acknowledgements

The authors also would like to thank the Ministry of Higher Education, Malaysia for supporting this research under Research Acculturation Grant Scheme (RAGS) Vot. R024 and Exploratory Research Grant Scheme (ERGS) Vot. E032.

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