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Effect of Preheated Fuel on Mixture Formation of Biodiesel Spray

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Abstract The key issue in using vegetable oil-based fuels is oxidation stability, stoichiometric point, bio-fuel composition, antioxidants on the degradation and viscosity thus influences to the different spray atomization and fuel air mixing characteristics. Purpose of this study is to investigate the effect of preheated biodiesel on fuel properties, spray characteristics and mixture formation. The detail behavior of mixture formation was investigated using the direct photography system with a digital color camera. This method can capture spray evaporation, spray length and mixture formation clearly with real images. Increased preheated fuel is found to enhance the spray penetration, resulting in increased the spray area and enhanced fuel-air premixing.

Introduction

In the biodiesel fuel (BDF) diesel combustion, the key element in combustion process is achieving sufficient rapid mixing between the injected fuel and the air in cylinder especially during ignition delay period. During this period, just after start of injection, the heat absorption process first occurs due to fuel evaporation and fuel thermal-decomposition. Subsequently, heat recovery process starts when fuel-oxidation generates heat. There were many studies on the fuel-air premixing that resulting from air entrainment which linked to the improvement of exhaust emissions [1-3]. Ishiyama et al. [4] has reported that the ignition process in diesel combustion, oxidation begins very early during ignition delay period and its supplies heat to the spray and causes cracking and gasification of fuel. It was reported that evaporation and atomization process during ignition delay prior to ignition process, combustible mixture is first formed at the midstream of the spray [5]. Thus, combustion process and exhaust emissions are more clearly observed by examining the characteristic of the air entrainment, endothermic and initial heat recovery during ignition delay period. The heterogeneous fuel-air mixture in the cylinder during the diesel combustion process contributes to the formation of soot particles, one of the most difficult challenges for diesel engine designers. These particles are formed in high temperature regions of the combustion chamber where the air-fuel ratio is fuel-rich and consists mostly of carbon with small amounts of hydrogen and inorganic compounds. This hydrocarbon material, called the soluble organic fraction, usually increases when biodiesel is used, offsetting some of the decrease in soot. Biodiesel's low volatility apparently causes a small portion of the fuel to survive the combustion process, probably by coating the cylinder walls, where it is then released during the exhaust process [6-10].

A second difficult challenge for diesel engine designers is NOx emissions. NOx emissions are associated with high gas temperatures and fuel lean conditions and, in contrast to most other pollutants, are usually observed to increase when biodiesel is used. NOx contributes to smog formation and is difficult to control in diesel engines because reductions in NOx tend to be accompanied by increases in particulate emissions and fuel consumption. While the bound oxygen on the biodiesel molecule may play a role in leaning the air-fuel ratio in NOx formation regions, the dominant mechanism seems to be the effect of changes in the physical properties of biodiesel, such as the speed of sound and bulk modulus, on the fuel injection timing. One of the most important properties of a diesel fuel is its readiness to auto ignite at the temperatures and pressures present in the cylinder when the fuel is injected.

As the air-fuel mixing process is a key element in diesel combustion, a good understanding of the formation of the spray is essential to improve fuel-air premixing, ignition process and combustion process. Many correlations for fuel spray penetration have been proposed in the literature, the dependent of penetration on ambient temperature and air motion especially the injection pressure characteristics [7, 11-14]. Comprehensive testing of the penetration and dispersion of both evaporating and non-evaporating sprays, and showed that the spray behavior is strongly dependant on in-cylinder density. The purpose of this study is to investigate the mixture formation of preheated diesel spray using direct photography system together with color digital video camera. The detail behavior of spray evaporation, spray interference and mixture formation during ignition delay period will be observed with the direct visualization method.

Experiment set up

Material Preparation. In this research, type of biodiesel that will be used in the experiment is produced from Crude Palm oil biodiesel (CPO) by transesterification. In this experiment, the biodiesel that will be used is taken from Universiti Tun Hussein Onn Malaysia (UTHM) biodiesel pilot plant. The biodiesel blending ratio is referring to the percentage mixture volume diesel and biodiesel according to the weight. Table 1 and 2 summarizes the comparison fuel properties characteristics of the standard fuel diesel (STD) and blending ratio biodiesel. The value of B5, B10, and B15 actually referring to the ratio of the mixture. The B5 biodiesel means the 5% from the mixture is biodiesel and the other 95% from the mixture are diesel. So that with the B10 biodiesel, 10% from the mixture must be biodiesel and other 90% must be diesel. Actually, the values at each biodiesel (B5, B10, B9 and B15) are referred to the ratio of the biodiesel in the mixture.

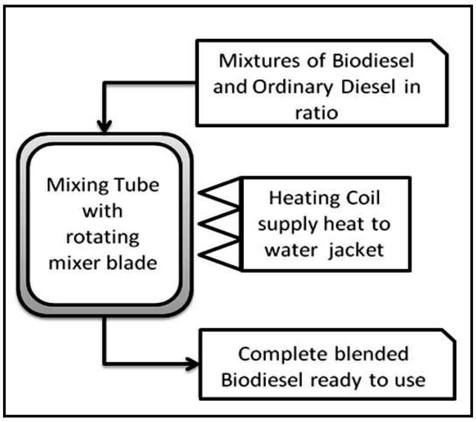
Table 1: Fuel properties at ambient temperature

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

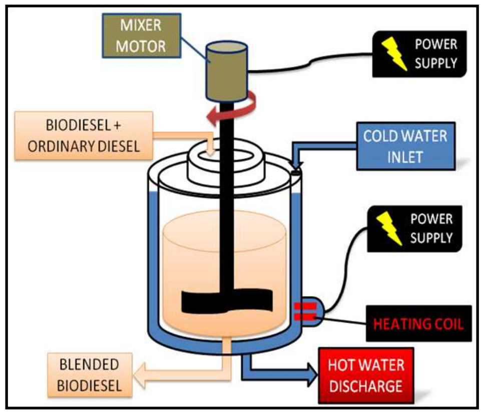
Table 2: Properties of blending biodiesel ratio at variant temperatur

Blending of Biodiesel	Density (g/cm^3)			Viscosity (cP)			Acid Value (mgKOH/g)			Flashpoint (°C)		
	30°C	25°C	6°C	30°C	25°C	6°C	30°C	25°C	6°C	30°C	25°C	6°C
B5	0.8553	0.853	0.8538	3.6	3.6	3.5	0.2805	0.2591	0.2943	86.1667	85.3333	85.3333
B10	0.8555	0.855	0.8563	3.5	3.8	3.7	0.3084	0.2662	0.3013	84	85	86.1667
B15	0.8562	0.8564	0.8568	3.6	3.6	3.5	0.3224	0.3221	0.3853	87.5	87.1667	85.5
B20	0.8575	0.8578	0.8575	3.5	3.5	3.8	0.3506	0.3644	0.3783	87.8333	89	86
B25	0.8583	0.8568	0.8589	3.6	3.7	3.7	0.5184	0.4201	0.5044	89.1667	92	93.1667
B30	0.8599	0.8584	0.8599	3.8	3.6	3.6	0.5055	0.4903	0.4626	87.8333	91.6667	88.1667
B35	0.8671	0.8613	0.8605	3.5	3.6	3.6	0.5323	0.5329	0.56	91.1667	92	93.1667
B40	0.8691	0.8656	0.865	3.7	3.7	3.7	0.5464	0.6163	0.5741	98	102	99.3333
B45	0.8651	0.868	0.8655	3.8	3.8	3.9	-	-	-	102.8333	104.3333	100.1667

A block diagram of blending process and schematic view of blending process are shown in Fig.1 (a) and Fig.1 (b), respectively. The purified palm oil methyl ester was then blended with STD in various concentrations for preparing biodiesels blend. During blending process, the blending machine was operated at 60^0C and the mixture was stirred at 70^0C for 1 hour. The rotating blade speed was adjusted to maintain the same speed at 270 rpm. The experimental work was performed in optically-accessible injector equipment intended for automotive application. A schematic view of the experiment set up is shown in Fig 2.

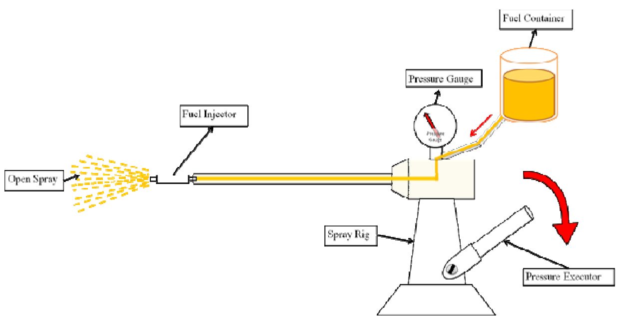


(a) Block diagram blending process

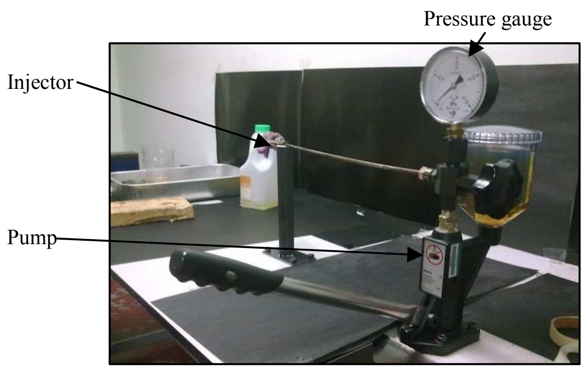


(b) Schematic of blending process

Fig. 1: Illustrating the blending process of producing oil palm blended fuel



(a) Schematic diagram for injection testing setup



(b) Injection testing sytem

Fig. 2: Experimental set up

Result and Discussion

Mixture formation of Spray. The effect of blending biodiesel ratio and injection pressure on mixture formation were investigated at the base standard diesel for ambient temperature (room temperature 24^0C) and heated temperature of 60^0C. Fig. 3 depicts the variation in spray structures as injection pressure and blending biodiesel ratio are varied under ambient temperature. As seen in Fig. 3, increased injection pressure and high biodiesel ratio, a great variation in the spray structure is observed compared with standard diesel. It promotes mixture formation and distributes larger amount of fuel between sprays thus creates good spray atomization and exhibits a greater amount of fuel-air premixing prepared for combustion. It seems that increment in injection pressure also affecting the spray tip penetration of the fuel but slightly difference in cone spray.

Images of spatial distribution of spray structures obtained at the variation injection pressure and heated fuel temperature at 60^0C are presented in Fig. 4. Referring to the images, as compared with baseline condition of standard diesel, increased injection pressure and preheat fuel can make spray tip penetration shorten. Preheat fuel at 60^{0}C, however, the spray cone becomes small as compared with Fig. 3 (without preheat). Changes in the spray penetration with different kind of fuel ambient condition are more clearly observed by examining the comparison of spray tip penetration as shown in Figure 5.

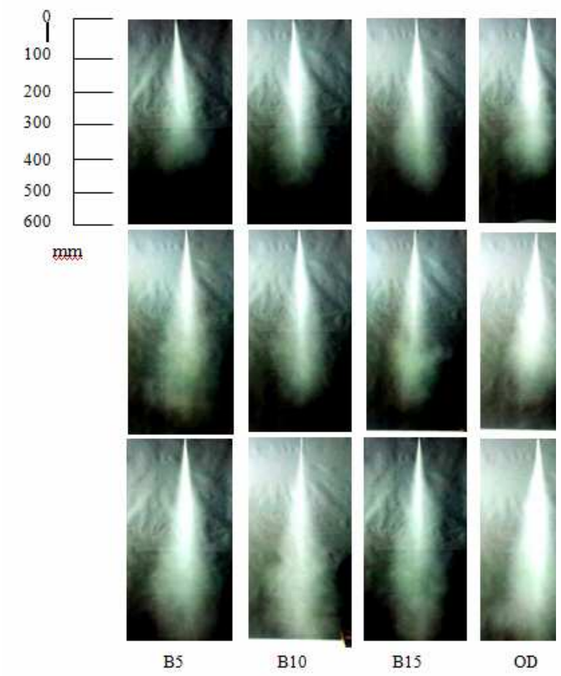


Fig. 3: Comparison of spray structures (ambient Temperature)

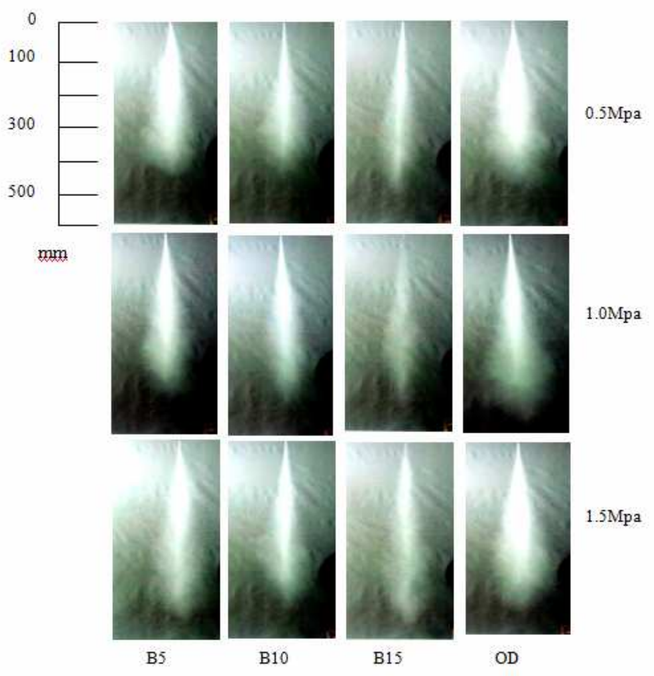


Fig. 4: Comparison of spray structures (Heated Fuel 60^{0}C)

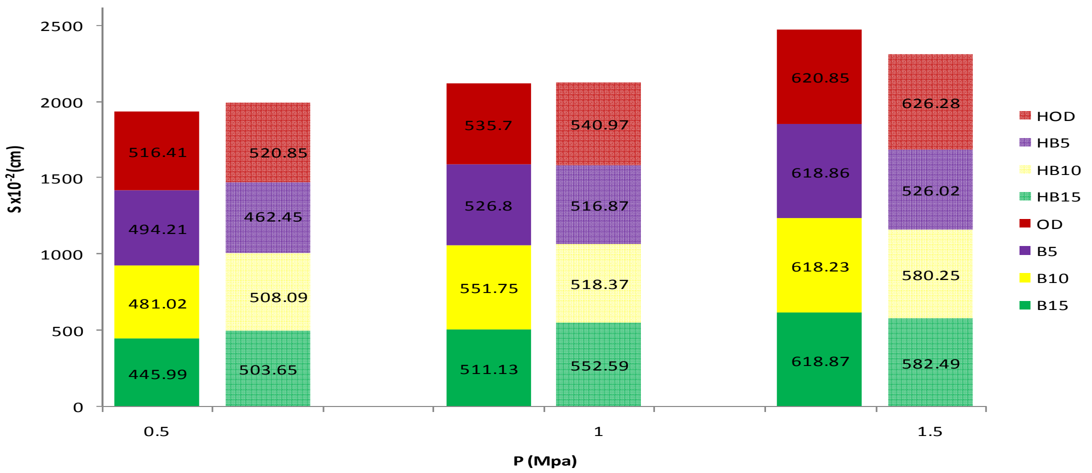


Fig. 5: Spray tip penetration comparison between room temperature and 60°C temperature

Fig. 6 illustrate the variation in spray angle comparison between room temperature (B%, B10, B15) and preheat fuel at 60°C temperature (HB5, HB10, HB15). The preheated condition fuel has higher spray angle as compared to ambient temperature. The largest spray angle heated ordinary diesel (OD) fuel at 1.0 MPa which is 13.17°. As seen in Fig. 6, under ambient condition, at the B15 ambient and 0.5MPa creates the smallest spray angle as compared with the preheat condition. This behavior could be associated with the low value of kinematic viscosity for fuel under preheat condition.

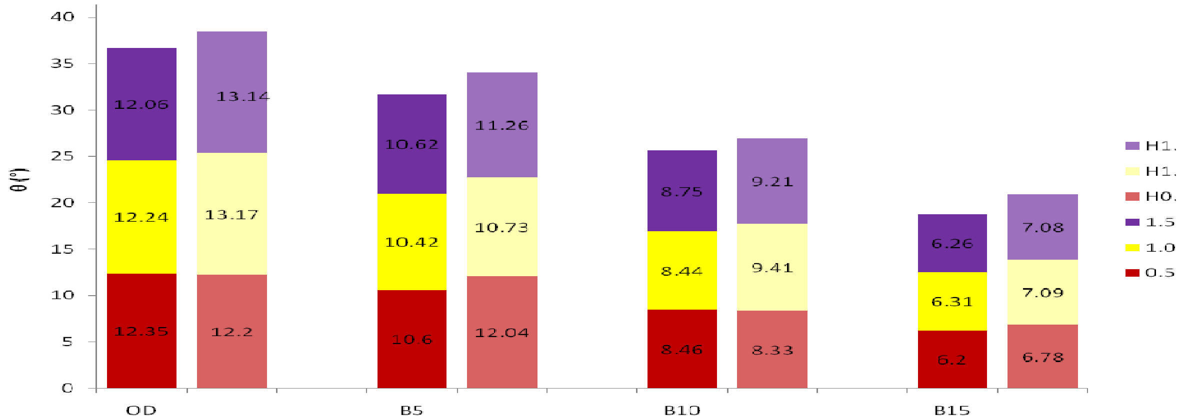


Fig. 6: Spray angle comparison between room temperature and 60°C temperature

Projected Spray Area. The projected spray area can be employed to represent the mixture formation behavior thus influences the mechanism of fuel-air premixing. Fig. 7 presents projected spray area versus the spray tip penetration for all types of blending ratio fuel. The influence of injection timing on spray area and the spray area are plotted versus the spray tip penetration. As seen in Fig. 6, the projected spray area is increasing with the increasing of spray tip penetration. Is clearly seen that the preheat biodiesel fuel present smaller spray area and attributes to smaller spray angle.

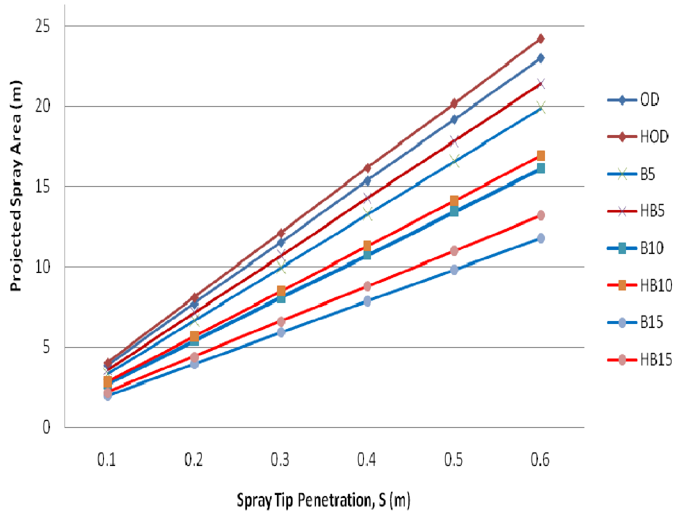


Fig. 7: Projected Area comparison

Spray volume. To further understand fuel-air mixing the spray area is investigated. Fig. 7 presents the variation in spatially spray area observed at different blending fuel ratio at different spray tip penetration. As seen in Fig. 7, under standard diesel promotes higher spray area compared to B5, B10 and B15. On the other hand, preheat fuel conditions also enhance the projected spray area, lengthen spray tip penetration and promote mixture formation at spray tip region. However, projected area is distributed at smaller region and suggests less air entrained into fuel spray under all variation blending ratio without preheat than with preheat condition.

Conclusion

In this research, design parameter of diesel combustion with variants in preheated fuel and injection pressure were investigated. Results are summarized as follows:

1. The biodiesel blending ratio B5, B10 and B15 gives longer spray tip penetration and smaller spray angle, projected area and volume than diesel fuel. In ambient condition, spray penetration of biodiesels is longer than ordinary diesel (OD).

2. Difference spray penetration between OD and biodiesels are reduced by increasing the injection pressure. Spray angle of OD is larger than biodiesel in any injection pressure. The spray angle is decreased with the decreasing of blending ratio of biodiesel fuel. Higher resistance strength and higher surface tension increased the spray angle.
3. Increased fuel temperature, the spray penetration and spray angle also increased. Increasing the fuel temperature also improve the projected spray area and spray volume than diesel due to higher viscosity.

References

[1] Jiro Senda, Nobunori Okui, Tokihiro and Hajime Fujimoto (2004). "On-Board Measurement of engine Perfomance and Emissions in Diesel Vehicle Operated with Bio-Diesel Fuel", SAE, 2004-01-0083.

[2] Amir Khalid, Shahrul Azmir Osman, Md Norrizam Mohamad Jaat, Norrizal Mustaffa, Siti Mariam Basharie, B. Manshoor, “Performance and Emissions Characteristics of Diesel Engine Fuelled by Biodiesel Derived from Palm Oil”, Applied Mechanics and Materials Vols. 315(2013), Trans tech Publications, Switzerland, pp 517-522

[3] Khalid, A., Yatsufusa, T., Miyamoto, T., Kawakami, J. and Kidoguchi Y. (2009) "Analysis of Relation between Mixture Formation during Ignition Delay Period and Burning Process in Diesel Combustion", SAE, 2009-32-0018, pp. 1-10.

[4] Ertan Alptekin, M.C (2008)., "Determination of the density and the viscosities of biodiesel-diesel fuel blends". Renewable Energy, 2008(33): p. 2623-2630.

[5] Ishiyama, T., Miwa K. and Horishiko, O. (1995). "A Study on Ignition Process of Diesel Spray, JSME, International Journal", Series B, Vol.38, No.3, pp.483-489

[6] Gerpen, J.V. (2002). "The basics of diesel engines and diesel fuels". University of Idaho Department of Biological and Agricultural Engineering, pp. 1-3.

[7] Crua C. "Combustion Processes in a Diesel Engine". Doctor of Philosophy. School of Engineering, University of Brighton; December 2002.

[8] Kalam, M.A., et. al. "Emissions and Deposit Characteristics of a Small Diesel Engine when Operated on Preheated Crude Palm oil", SAE Paper 2005-01-3697, 2005.

[9] Hamasaki, K., et. al. "Utilization of Palm Oil for Diesel Fuel", Trans. Jpn. Soc. Mech. Eng. 68 (667), pp. 958-963, 2002.

[10] H. Ban Quan et al. (2003), "Study on Combustion and Emission Characteristic of Diesel Engines sing biodiesel blended Diesel Fuels". (01-0762)

[11] Richard L. Bechtlold (2002). "Alternative Fuels-Transportation Fuels for Today and Tomorrow". SAE International.

[12] S. L. Cheah (2004). "Analysis of Engine Performance using Palm Oil Methyl Ester". Degree in Bachelors of Engineering (Mechatronics). Thesis. Faculty of Engineering, University of Southern Queensland.

[13] Amir Khalid and Bukhari Manshoor, "Effect of High Swirl Velocity on Mixture Formation and Combustion Process of Diesel Spray", Applied Mechanics and Materials Vols. 229-231 (2012), Trans tech Publications, Switzerland, pp 695-699.

[14] Amir Khalid and Bukhari Manshoor, “Analysis of Mixture formation and Flame Development of Diesel Combustion using a Rapid Compression Machine and Optical Visualization Technique”, Applied Mechanics and Materials Vols. 315(2013), Trans tech Publications, Switzerland, pp 293-298