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A STUDY ON SPRAY CHARACTERISTICS OF STRAIGHT VEGETABLE OIL

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ABSTRACT

Biodiesel is considered a promising alternative fuel to reduce the dependent on fossil fuel without any major modification on existing engines system. Compared to diesel fuel, biodiesel has several superior combustion characteristics. It has the advantages of high biodegradability, excellent lubricity and no sulfur content. For example, when biodiesel is used inside the engine, approximately 10wt% of its oxygen content promote more complete combustion process and effectively reduce unburned hydrocarbons (UHC), carbon monoxide (CO) as well as suspended aerosol carbon granules. Although biodiesel has many advantages on the fuel properties, the fuel consumption rate or lower horsepower output are still need to be improved. This is due to the differences in fuel properties especially the kinematic viscosity between diesel fuel (GO), biodiesel fuel (BDF) and straight vegetable oil (SVO). In this study, the effect of kinematic viscosity of SVO on fuel injection spray characteristicare investigated using constant volume high pressure spray chamber.

***Keywords**:* diesel spray, solid vegetable oil SVO, kinematic viscosity, droplets, penetration, cone angle.

INTRODUCTION

Biofuel refers to fuel that are mainly derived from biomass or bio wastesuch as a vegetable oil or animal fat-based diesel fuel. Unlike petroleum diesel, biofuel is a renewable resource.The use of biofuelfuelcould be the solution to the increasing transportation energy crisis. Biofuel perform as well as regular diesel fuel and can be used with diesel engine with less modification needed.Laboratory tests, as well as road tests, have proven that biofuel have equally horsepower and torque as diesel fuel. With the continued rise of fuel prices, biofuel is set to become more popular as one of a fuel replacement option in the transportation industries. Some advantages of biofuel application are engines will last longer when using biofuels. Traditional diesel engines have a much higher rate of engine wear due to oil lubricant problem. Using biofuel could improve lubricity inside the engine thus lengthen engine durability. New regulations require diesel engines to lower sulfur emissions considerably, making biofuel blends much more attractive as a practical fuel to use.

On the other hand, some disadvantages of biofuel application are biofuel production is currently more expansive than diesel. Other problem is that some properties of biofuel make it undesirable for use at low temperatures, which become problematic in cold climates region. Most significantly, biofuel contains less energy value than diesel, leading to reductionofengine power output. Furthermore, biofuelhasyet shown no significant effect on the energy efficiency of any test engine. The energy content per gallon of biofuel is approximately 10% lower than that of diesel fuel. Vehicles running on biofuel are therefore expected to achieve about 10% fewer miles per gallon of fuel than diesel (Senatore and Cardove, 2000; IEA).Other problems include limited oxidation and storage stability, a tendency to form deposits, corrosion issues, cold flow problems and questionable stability from diverse feed-stocks. In addition to this research, experiment on spray characteristics of biofuel was done in order to analyze the affect of biofuel kinematic viscosity on fuel spray. Many know that biofuel fuel has high potential of replacing the usage of diesel. However, biofuel is well known for its high level of the kinematic viscosity. The high level of kinematic viscosity could cause some sort of resistance of fuel flow during fuel injection, effecting the spray geometry thus the atomization process (Babu and Devaradjane, 2003).

EXPERIMENTAL SETUP

Figure 1 shows optical setting for biofuel experiment with single spark shadowgraph method. In this setting, Digital Single Lens Reflex (DSLR) Nikon D60, prime lens: Nikkor 50mm f/1.4 was used for wide angle photography. ND filter was used in order to reduce by 30% the brightness of light spark emitted by spark head.

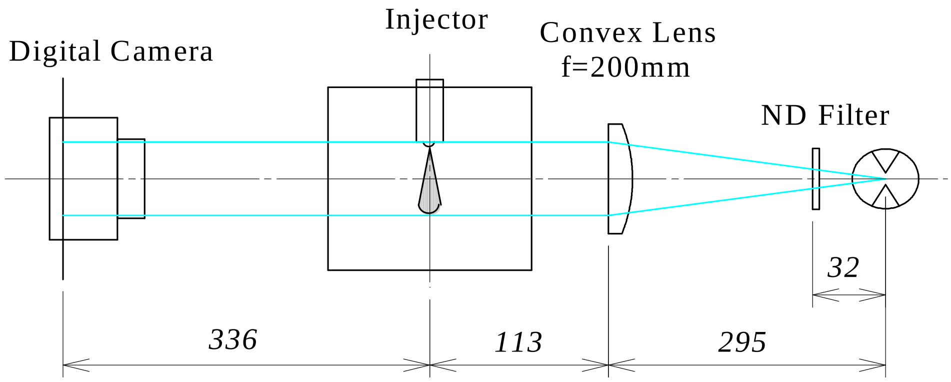

Figure 1: Single spark optical setting for biofuel spray experiment

Test Fuels Properties

Properties of straight vegetable oil (SVO) used for this experiment are shown in Table 1. Referring to Table1, obviously kinematic viscosity value for SVO fuel is extremely high compared to GOfuel.Kinematic viscosity for SVO is almost 14.5 times higher than GO fuel. Pre experiment was done to analyze the affect of fuel temperature on kinematic viscosity.Theresult of the experiment is plotted in Figure 2. All the test fuel samples (GO, BDF and SVO) shows its kinematic viscosity value are declining with the increased of the fuel temperature. GO and BDF shows same degree of declination pattern but obviously, SVO shows rapid declination at different of 100K fuel temperature. Figure 3 shows distillation characteristics of the test fuels. The measurement was strictly done following the JIS K2254 which is Japan Standard Measurement Method for fuel distillation test. The result shows that BDF has 95% high-end distillation component compared to GO. Meanwhile, SVO shows highest distillation measurement among others test fuels. Pre experiments results shows that SVO has highest kinematic viscosity and highest distillation among others test fuels which will affect spray characteristic when injected into engine.At the same time, Figure 3shows that fuel properties change significantly with the temperature, which affects the spray development and spray penetration

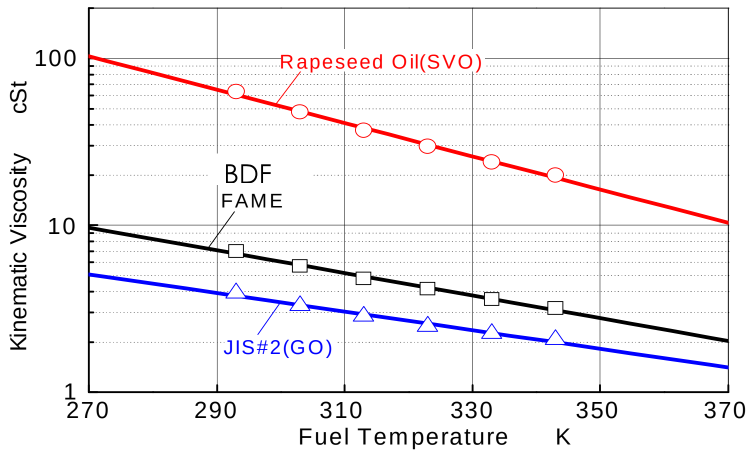

Figure 2: Affect of fuel temperature on kinematic viscosity

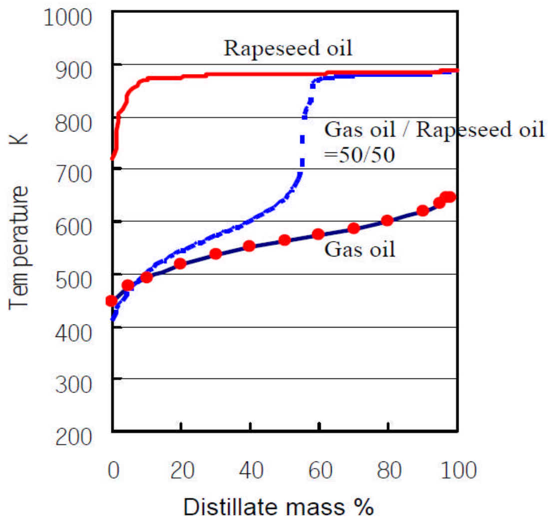

Figure3: Distillation characteristic of test fuels

Table 1: Properties of diesel fuel (GO) and straight vegetable oil (SVO)

Fuel and Notation		GO	SVO
Density 15°C	g/cm^3	0.827	0.911
Kinematic viscosity	mm^2/s@303K	3.30	47.78
Carbon	wt-%	0.86	0.78
Hydrogen	wt-%	0.14	0.11
Oxygen	wt-%	0	0.11
Lower heating value	kJ/kg	42.70	38.14
Cetane index		58.2	Unknown

RESULTS AND DISCUSSIONS

Spray comparison of SVO, BDF and GO

Figure 4 shows spray images of SVO, BDF and GO fuel taken at ambient temperature T_i=298K, fuel injection pressure P_{inj}=40MPa and time after start of injection t=0.5ms. Referring to the images, SVO spray penetration was obviously shorter than BDF and GO spray. Moreover, narrow spray cone angle can be seen from SVO spray from nozzle outlet until spray tip area. No structures like branches developed along SVO spray boundary as can be seen in BDF and GO spray. This is due to the high level of kinematic viscosity for SVO fuel as shown in Table 1. Meanwhile, BDF has similar value of kinematic viscosity compared with GO thus its spray behavior shows similar characteristics with GO spray.

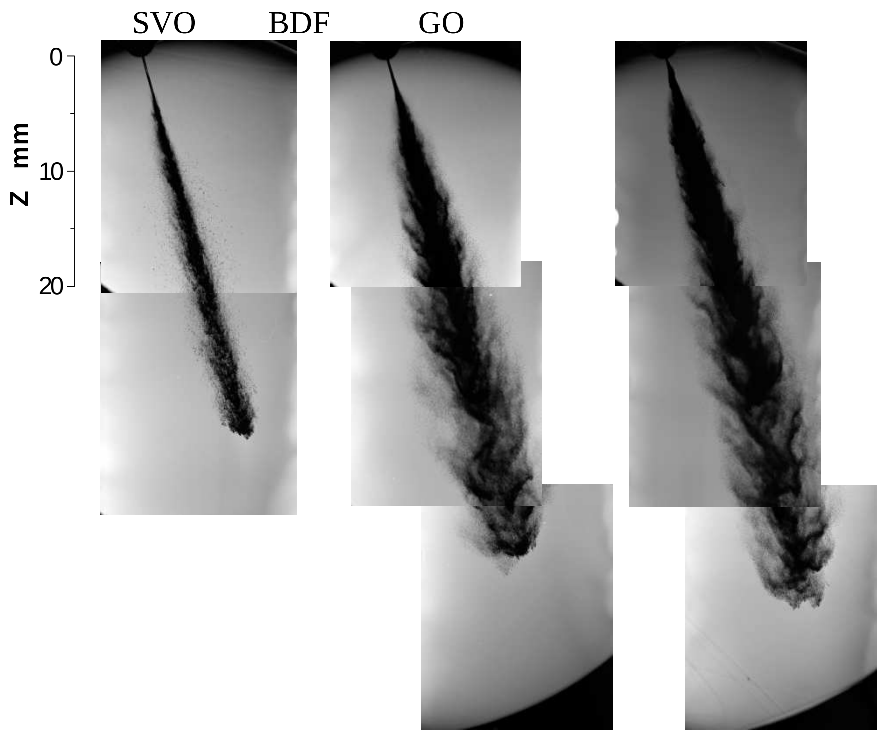

Figure 4: Comparison of spray structures between SVO, BDF and GO sprays (T_i=298K, P_{inj}=40MPa, t=0.5ms)

Effect of Injection Pressure and Ambient Temperature on SVO Fuel Spray

Figure 5 shows the effect of injection pressure P_{inj}=40MPa and P_{inj}=70MPa on SVO spray penetration (left) and magnified images of droplets at spray boundary area (right). The images were taken using single spark photography method as shown in Fig. 1. Referring to Fig. 5, spray at P_{inj}=70MPa shows longer penetration length compared to P_{inj}=40MPa. Furthermore, structures like branches can be seen developed along spray boundary region. Magnified images of droplets shows more droplets exist inside spray boundary region at higher injection pressure of P_{inj}=70MPa. Generally, high injection pressure spray also produces relatively small-size droplets and as a result, small size droplets could lead to a better atomization process[4]. Figure 6 shows SVO spray penetration (left) and magnified images of droplets at spray boundary area (right) taken at higher ambient temperature of T_i=700K. Referring to Figure5 and Figure 6, SVO spray at higher ambient temperature T_i=700K shows longer penetration length compared to lower ambient temperature T_i=298K. In addition, SVO spray at high ambient temperature produce similar spray structures as GO fuel spray structures, for example, penetration, cone angle, structures like branches, etc. As shown in Figure2, kinematic viscosity level of SVO decreased with increased of fuel temperature.Therefore, SVO spray at high ambient temperature could produce similar spray structures as GO spray.

Figure 7 shows detail observation inside spray boundary region between GO and SVO. Magnified images of droplets shows no vapor phase can be visibly seen inside SVO spray boundary region. Contrary, as shown in Figure7, GO fuel spray at T_i=700K and P_{inj}=70MPa shows large vapor phase developed at spray boundary region. From the observation, it can be conclude that SVO spray at high ambient temperature and high injection pressure could promotes faster atomization process but slower vaporization compared to GO fuel.This drawback has tendency to increase exhaust emission when apply inside low load engine.

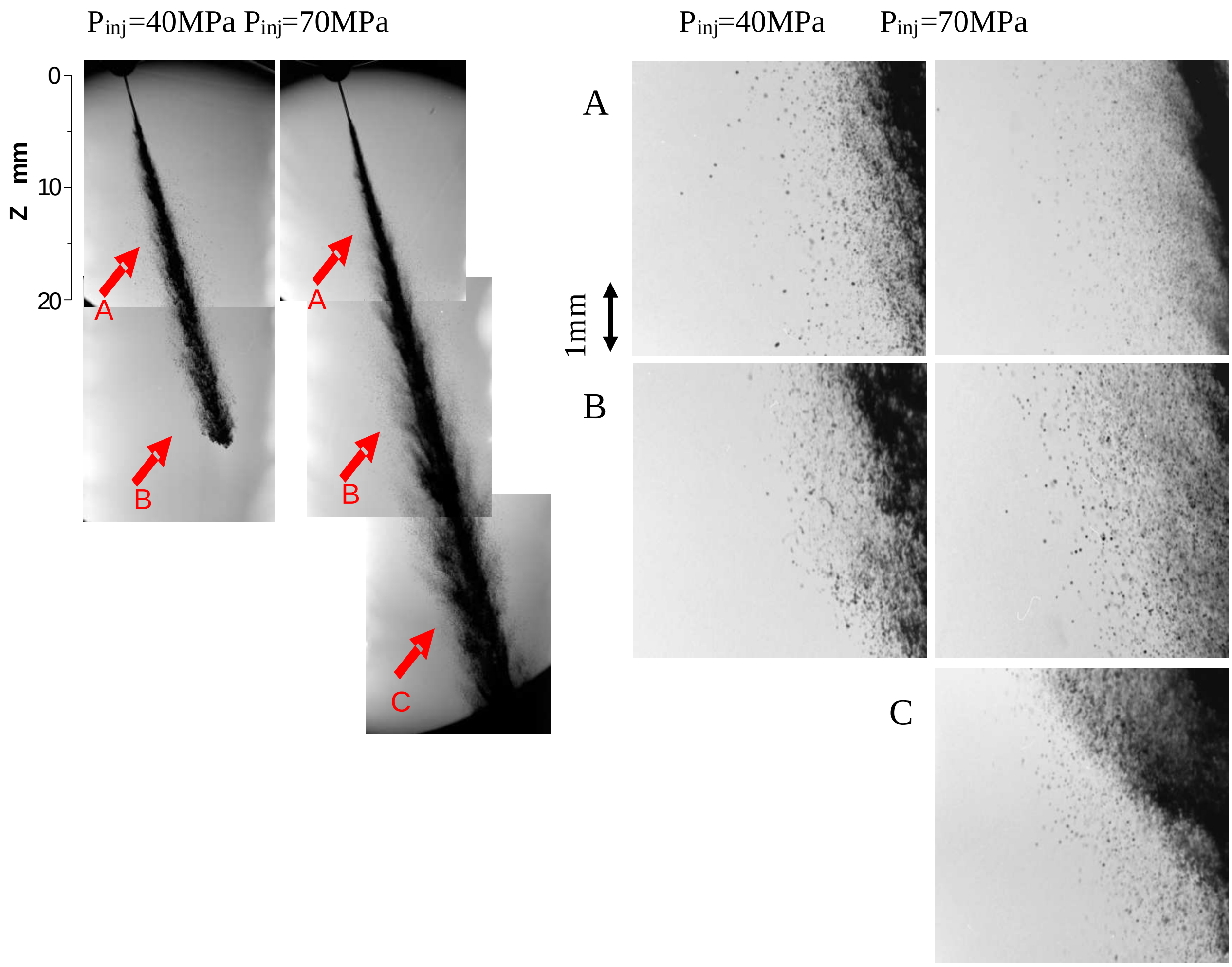

Fig.5 SVO spray images and magnified images of SVO droplet at different injection pressure (T_i=298K, t=0.5ms)

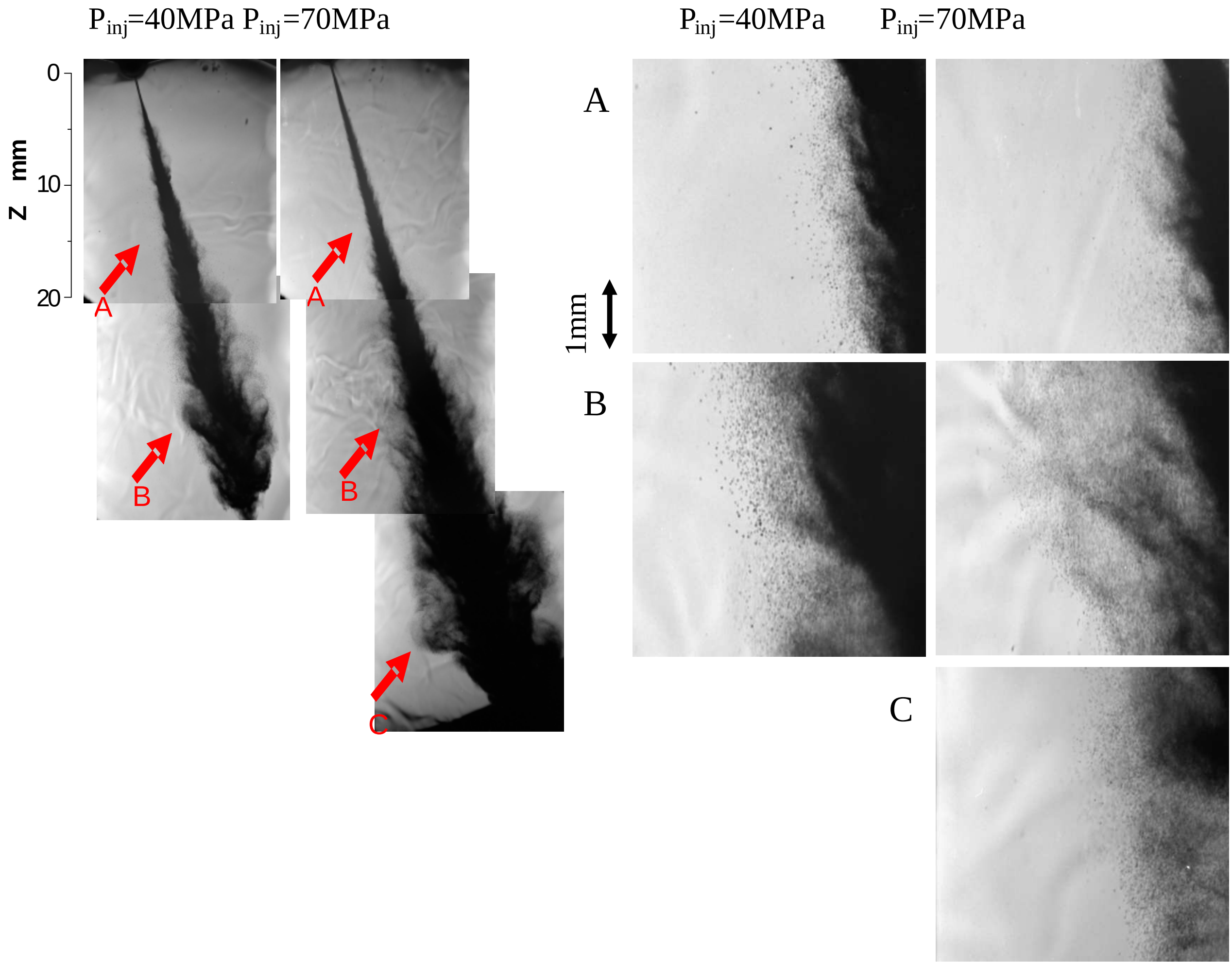

Figure 6: SVO spray images and magnified images of SVO droplet at different injection pressure (T_i=700K, t=0.5ms)

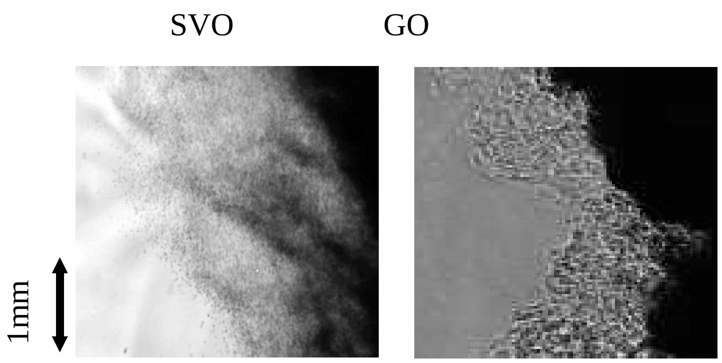

Figure7: Spray characteristics at spray boundary region (T_i=700K, P_{inj}=70MPa)

CONCLUSION

Improvement of SVO spray by various control strategies have been done and reported in this paper. The conclusions of the results areshown as follows:

1. Kinematic viscosity value highly effect spray geometry such as penetration and cone angle. SVO spray penetration measured shortest and narrow cone angle compared with BDF and GO spray in T_i=298K. These are due to the high level of kinematic viscosity inside SVO compared to BDF and GO fuel.
2. High injection pressure spray shows improvement in SVO fuel penetration length and development of structures like branches along spray boundary. High injection pressure spray also produces relatively small-size droplets and could improve atomization process for SVO spray.
3. SVO spray at high ambient temperature produce similar spray structures as GO spray due to kinematic viscosity level of SVO decreased with increased of fuel temperature. High ambient temperature spray produce smaller droplets size that could promoteatomization but slower vaporization compared to GO fuel cause increase of emission when running in low load engine.

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