Jurnal Mekanikal
December 2011, No 33, 32-39

PERFORMANCE AND EMISSION CHARACTERISTICS OF A DIESEL ENGINE FUELED BY RAPESEED OIL BIO-FUEL

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ABSTRACT

This study had used straight vegetable oil (SVO) particularly neat rapeseed oil as a fuel in a direct injection diesel engine. Combustion performance and exhaust emissions of using the fuel have been measured from no load up to full load engine condition. For comparison diesel fuel JIS#2 have been used. SVO gives higher NOx but lower smoke emissions at high load compared with JIS#2. Lower smoke emissions at high load is due to oxygen content in the SVO that can eliminate partially unburned fuel at stratified fuel rich zone during combustion. Enhanced combustion raises the temperature inside the combustion chamber and caused higher NOx emission. In addition of using SVO as fuel, this study also had blend several percentages of ethanol into SVO with the presence of octanol as surfactant. As percentage of ethanol increased in this SVO-ethanol blend, smoke and particulate emissions reduced with unchanged NOx level. This is because the reduction of kinematic viscosity of SVO-ethanol blend improves the atomization and vaporization of injected fuel droplets that leads to lower particulate emission. Simultaneous reduction of NOx and particulate emissions can be obtained by transform the SVO into an emulsion fuel by blending some percentages of water into SVO with existence of castor oil as surfactant. Evaporation of water during combustion reduces the combustion temperature and causes the reduction of NOx emission. Reduction of particulate emission is due to water gas reaction. However, the use of SVO emulsion in diesel engine shows deterioration of CO and THC emissions.

Keywords: *Diesel engine; diesel emission; straight vegetable oil; ethanol blend; emulsion*

1.0 INTRODUCTION

Recently, crude oil reaches the maximum price over 100 dollar US per barrel surpass the price during Oil Crisis around 1980's. In order to sustain the development of human's life, alternative fuel that can take over the function of petroleum base fuels need to be found. Figure 1 shows the prediction of Exxon Mobil Company on world demand and

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production quantity of petroleum [1]. The figure indicates that the world demand on petroleum is surpass the production quantity with the production quantity decrease 4~6% in 2003. This make some alternative fuel particularly bio-fuel become popular in a growing number of countries around the world.

Diesel engine have been accepted world wide to be the engine that can produce energy of using either petroleum based fuel or renewable alternative fuel. Many previous studies had used bio-diesel, which define as fatty acid methyl ester or ethyl ester as fuel in the diesel engine. The emissions of bio-diesel are generally close to those emitted by petroleum based diesel fuel due to it's fuel properties that have lower kinematic viscosity and density compared with their original state of fatty acid particularly vegetable oil [2-5]. However, it is important to be noted that bio-diesel gives a higher price compared with diesel fuel. Furthermore, in the process to obtain bio-diesel through transesterification process, byproduct known as glycerin is produce and may contaminate environmental water if it is disposed with improper manner throughout the water drainage.

Strict exhaust emission regulations introduced by governments world wide is also become one of major challenge for engineers in this field to realize the utilization of bio-fuel in diesel engine [6]. This study is presenting some investigation on emission characteristics and emission improvement of straight vegetable oil (SVO) particularly neat rapeseed oil as fuel in direct injection diesel engine. The test has also been carried out by altering the fuel properties of SVO by blending it with some percentages of ethanol and by transforms it into water emulsion fuel.

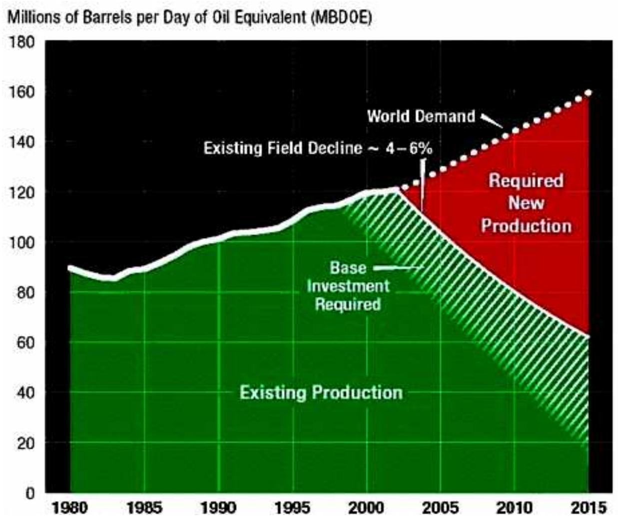

Figure 1 : Worldwide petroleum demand and production quantity

2.0 EXPERIMENTAL DETAILS

2.1 Fuel Production and Properties

Table 1: Test Fuel Properties

		JIS#2	SVO		
			Neat	Ethanol 15%	Water 15%
Density	g/cm^3	0.827	0.911	0.892	0.924
Kinematic viscosity	cSt@30℃	3.531	47.78	18.49	67.33
A/F stoichimetry		14.43	12.22	12.25	10.23
Lower heating value	MJ/kg	42.70	38.14	36.88	31.56
Oxgen content	wt.%	0	11.09	14.21	23.70

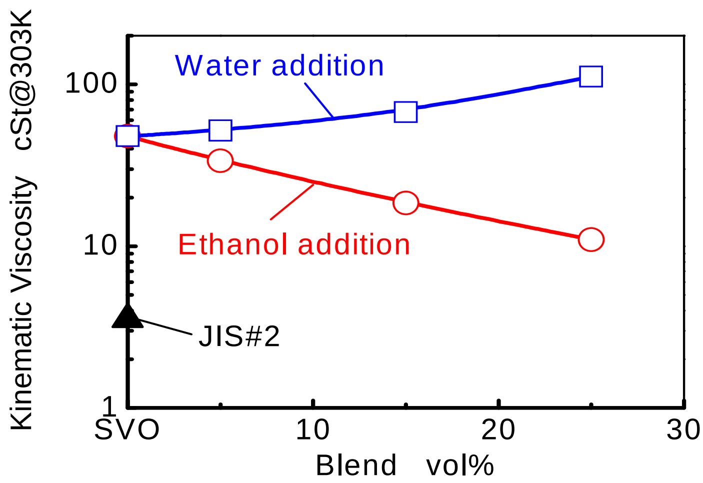

Figure 2 : Kinematic Viscosity of Blended Fuels

Table 1 shows fuel properties for tested fuels. Neat SVO is an oxygenated fuel with lower stoichiometric air-fuel ratio and lower heating value compared with JIS#2. SVO also has higher density and kinematic viscosity. However, blending SVO with 15% ethanol did reduce the SVO kinematic viscosity by 2.5 times. In contrast, emulsification of SVO with water increases the kinematic viscosity. These kinematic viscosity changes are shown in Figure 2. Surfactant for SVO-ethanol blend is octanol and for SVO emulsification is castor oil.

Stirred SVO with ethanol or water is unstable and will separate into two phases within several hours. Therefore, surfactant was added in order to stabilize the blended fuel from forming separated phases. However, these blended fuels are considered as not blended well due to cycle fluctuation that occur during combustion. Therefore, ultra sonic wave (USW) device has been used to further stabilized and well blend the fuels. The effects of using ultra sonic wave during fuel production on combustion performance can be seen as shown in Figure 3. It can be seen that with using USW, fuel is injected at constant timing and produce stable cycles. The process of making blended fuels is shown in Figure 4. The sequent of SVO, surfactant and ethanol or water is poured into the pre mix tank. While the mixture being stirred, the pump transmits the mixture to pass through the ultra sonic wave device. Well-blended fuels can be produced with frequency of ultra sonic wave at 20kHz and USW charging duration of fuel at 25ml/min.

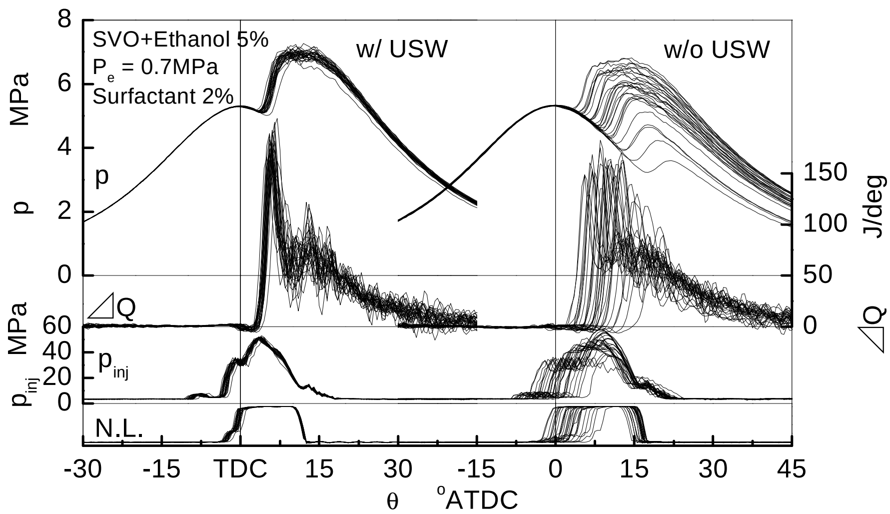

Figure 3: Effect of ultra sonic wave on combustion performance

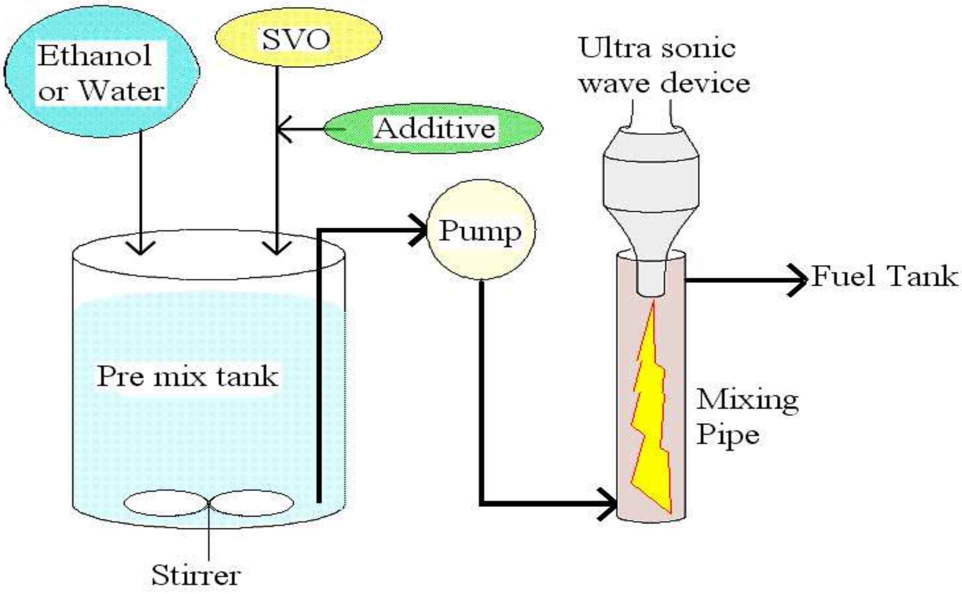

Figure 4 : Stirrer process of making blended fuels

2.2 Experimental Setup

Table 2 : Engine Specifications

Engine type	Direct injection
Aspiration	Naturally aspirated
Number of cylinder	Single
Displacement	857 cc
Bore X Stroke	Ø102 x 105mm
Compression ratio	17
Combustion chamber	Toroidal (STD)
Swirl ratio	2.2
Injection system	Bosch type
Nozze opening pressure	19.6 MPa
Nozzle	150°-4 X 0.29

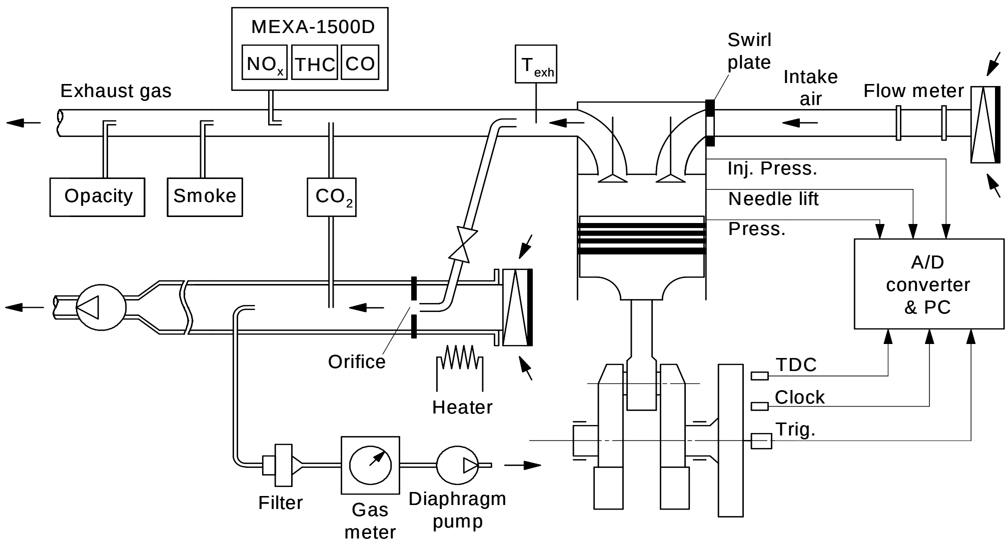

Figure 5 : Schematic Diagram of Experimental Apparatus

The test engine is a four-stroke single cylinder naturally aspirated direct-injection diesel engine (Yanmar NFD170). The base engine specifications are given in Table 2. The engine is 102 mm cylinder diameter and 105 mm stroke. The compression ratio is 17. Standard mechanical injection pump (PFR-IAW) is used and injection nozzle specifications are four-hole, hole diameter of 0.29 mm with spray angle of 150°and nozzle opening pressure is 19.6 MPa. Static injection timing was fixed at –10°ATDC. Standard combustion chamber (STD) is toroidal type and the swirl ratio is 2.2.

Figure 5 shows the schematic diagram of experimental apparatus. Engine performance and emissions data are obtained under stable operating conditions at engine speed of 1800 rpm and coolant temperature of 80□. A mini-dilution tunnel with 70mm inner diameter and 680mm in length is employed for sampling particulate emissions. A part of exhaust gas is introduced to the mini-tunnel at the 1.6m downstream from exhaust valve and diluted at dilution ratio of 10 [7]. Particulate concentrations are determined by measuring filter weight before and after sampling. The soluble organic fraction (SOF) is extracted from the particulate sampling filter by Soxhlet extraction method using dichloromethane as solvent. Total hydrocarbons (THC), CO and NOx concentration are measured with a diesel exhaust gas analyzer (HORIBA MEXA-1500D) and smoke density is measured with a Bosch smoke meter. Smoke is also measured using Opacity smoke meter (HORIBA MEXA-130S). Cylinder pressure is measured at every 0.5°crank angle with a piezoelectric pressure transducer (Kistler 601A). Pressure diagrams are obtained as a function of crank angle by averaging 128 successive cycle data.

3.0 RESULTS AND DISCUSSION

3.1 Straight Vegetable Oil (SVO)

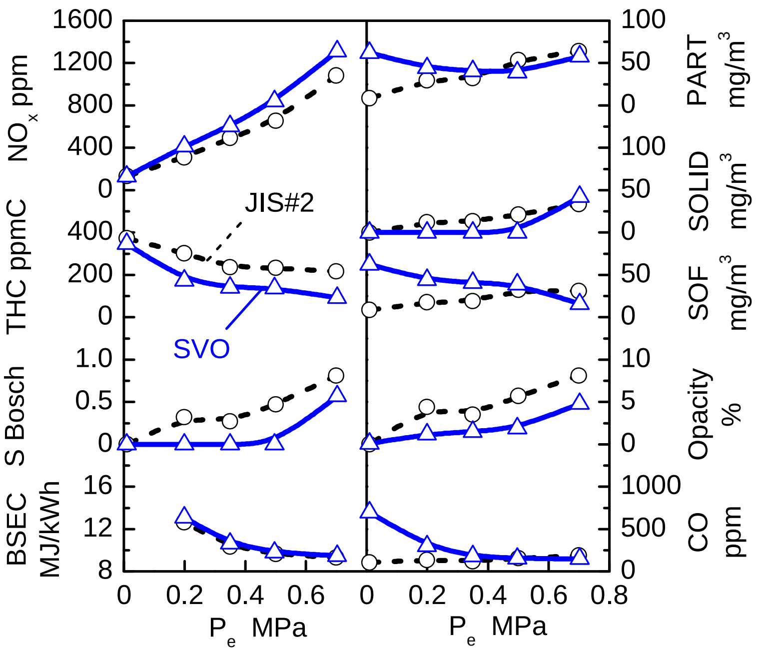

Figure 6 : Emission characteristics of neat SVO compared with JIS#2

Figure 6 shows comparison of emissions concentration versus engine load condition P_e between JIS#2 and SVO. NOx concentration shows slight increment for SVO compared with JIS#2. Oxygen content of SVO can enhanced the combustion performance and produce higher in-cylinder temperature that leads to a higher NOx emission. Low smoke density is obtained because of positive effect of oxygen content in SVO which contributes to improve combustion in fuel rich region where soot is formed. Particulate emission is a summation of SOLID and SOF. The trend of SOLID against P_e is almost same as smoke. However, particulate emission changes differently with P_e. Particulate emission from SVO show slightly lower compared with JIS#2 at high engine load but increase gradually at idling engine condition. SVO has low level of SOF emission at high engine load, but increase gradually as engine load decreases. It can be seen that the increment of SOF emission from SVO gives direct effect on the high concentration of particulate emission at low loads. This is mainly due to high kinematic viscosity of SVO [8, 9]. THC and CO emissions of using SVO increase gradually at lower loads engine condition. However, THC emission for SVO is slightly lower than JIS#2 at all loads engine condition. This might due to combination affect of oxygen content and low stoichiometric air-fuel ratio of the fuel.

3.2 SVO –Ethanol Blend

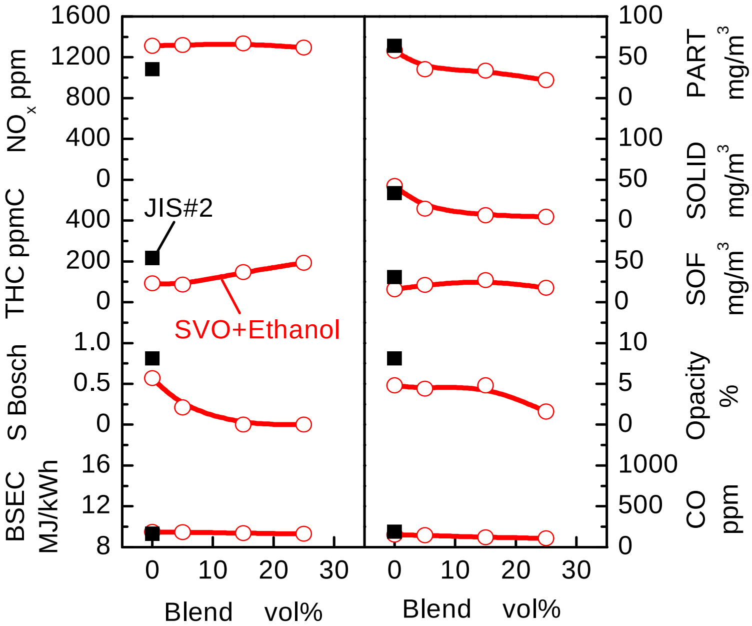

Figure 7 : Emission characteristics of SVO -ethanol blend compared with JIS#2

Figure 7 shows the effect of ethanol percentage in the SVO-ethanol blend on emission characteristics at full load engine condition (P_e=0.7). It can be seen that smoke and particulate emission are reduced as ethanol percentages increased in the SVO-ethanol blend. This is mainly because the kinematic viscosity of SVO-ethanol blend has been reduced as percentage of ethanol in the blend increase. Lower kinematic viscosity can enhanced atomization of injected fuel from nozzle. This can promote air-fuel mixture in the combustion chamber and increase oxidization of fuel. Hence, this can reduce the formation of smoke as well as particulate emissions.

NOx is remains unchanged as percentage of ethanol increase. Although the reduction of kinematic viscosity can promote the combustion performance, the increment of ethanol percentage reduces the lower heating value of the SVO-ethanol blend. This may produce the same in-cylinder temperature as of neat SVO and remain the NOx formation level.

3.3 SVO Water Emulsion

Simultaneous reduction of NOx and particulate emission can be obtained by emulsifying SVO. As shown in Figure 8, NOx and particulate emissions is reduced with increment of water percentage.

The existence of water in the fuel cause the temperature in the combustion chamber decreased. This is because the flame heat is lost to the latent heat and sensible heat during water evaporation. In addition, water gas reaction, which is an endothermic reaction that occurs in the combustion chamber, can reduce in-cylinder temperature and controlled the formation of NOx emission.

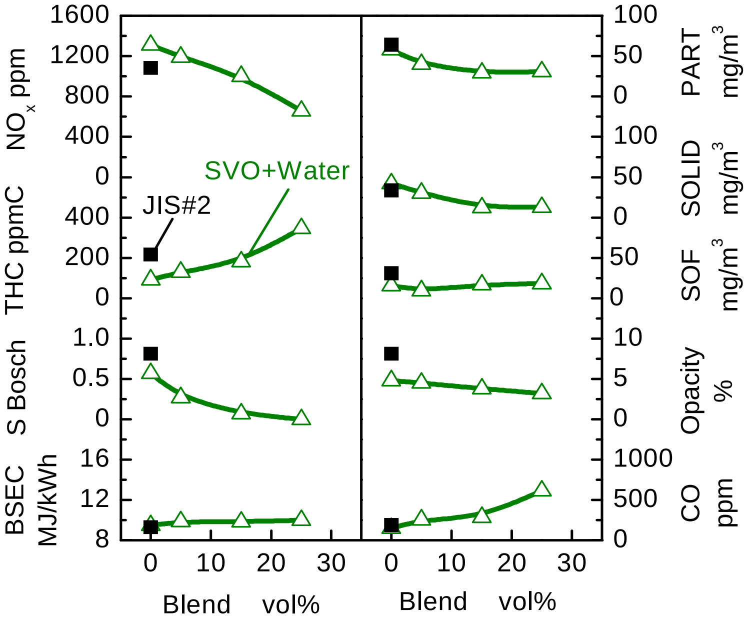

Figure 8 : Emission characteristics of SVO water emulsion compared withJIS#2

Water gas reaction can reduce the formation of particulate emission. Existing water will react with unburned carbon to produce carbon monoxide or carbon dioxide. This explains reduction of smoke and particulate emissions by using emulsified SVO as fuel in diesel engine.

The increment of CO emissions of using SVO emulsion has been predicted due to water gas reaction that can produce CO as a product. THC emission is also increase as percentage of water increase in the fuel. This is because the significant higher kinematic viscosity of the SVO emulsion restrains the atomization of injected fuel and being emitted through exhaust port as an unburned fuel.

4.0 CONCLUSION

Promoted combustion due to oxygen content in SVO caused higher NOx emission. However, the oxygen content in SVO can eliminate partially unburned fuel at stratified rich zone and produce lower smoke. As for SVO-ethanol blend, smoke and particulate emissions reduced with unchanged NOx level. This is because the reduction of kinematic viscosity of blended fuel improves the atomization of injected fuel droplets that leads to lower particulate emission. Simultaneous reduction of NOx and particulate emissions can be obtained by transform the SVO into emulsion fuel. Evaporation of water during combustion reduces the combustion temperature and causes the reduction of NOx emission. Reduction of particulate emission is due to water gas reaction. However, the use of emulsion fuel shows deterioration of CO and THC emissions with the increasing of water percentage.

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