



AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com



Experimental Investigations on the Use of Preheated Biodiesel as Fuel in Various Load Conditions of Diesel Engine

¹Amir Khalid, ¹M. Syamim, ¹N. Mustaffa, ¹Azwan Sapit, ¹Izzuddin Zaman, ¹B. Manshoor, ²Syahrullail Samion

¹Automotive Research Group (ARG), Centre for Energy and Industrial Environment Studies (CEIES), Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400 Johor, Malaysia.

²Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.

ARTICLE INFO

Article history:

Received 25 January 2014

Received in revised form 12

March 2014

Accepted 14 April 2014

Available online 25 April 2014

Keywords:

Preheated, Crude palm oil, Straight vegetable oil, Performance, Emissions, Diesel engine

ABSTRACT

Crude palm oil (CPO) and straight vegetable oil (SVO) offers significant potential for alternate fuel in diesel engine. Biodiesel is the alternate fuel which is derived from renewable is non-toxic, have higher biodegradability, free of sulphur, no aromatics and its oxygen content of about 10-11% compared with diesel fuel. However, the high viscosity and the major chemically bound oxygen component in the biodiesel fuel play as a key element in combustion process especially during the fuel-air premixing. These characteristics thus predominantly influences to the performance and emissions in the exhaust gas. Purpose of this study is to investigate the effects of CPO biodiesel fuel and SVO together with engine speed on the combustion process, combustion characteristics, exhaust emissions and engine performance under various of load conditions. The blending of CPO biodiesel and SVO was varied from 5vol% ~ 15vol% and preheated fuel temperature from 50°C. The engine speed was varied from 1500 rpm~3000 rpm and the load test conditions up to 50% are considered. The performances parameter study of diesel engine in brake power, torque and flywheel torque are described together with the emissions parameter such as opacity, hydrocarbon (HC), nitrogen oxide (NO_x), carbon oxide (CO), carbon dioxide (CO₂) and oxygen (O₂). Increased of load condition and preheated biodiesel blends temperature promotes more rapid engine performance but exhibit relatively small variations in emissions production. Increased preheated fuel temperature, higher in torque value and brake power increases significantly as the engine speed increases.

© 2014 AENSI Publisher All rights reserved.

To Cite This Article: Amir Khalid, M. Syamim, N. Mustaffa, Azwan Sapit, Izzuddin Zaman, B. Manshoor, Syahrullail Samion., Experimental Investigations on the Use of Preheated Biodiesel as Fuel in Various Load Conditions of Diesel Engine. *Aust. J. Basic & Appl. Sci.*, 8(5): 423-430, 2014

INTRODUCTION

The depletion of world non-renewable source such as petroleum has led to the growing interests in attention to seek an alternative fuel for decentralized the renewable sources. Thus, biodiesel derived from biological ingredients instead of petroleum is offer a great option in automotive combustion. However, most biodiesel fuels have faced the problem where the fuels are not operating efficiently due to the variant in fuel properties thus influences the combustion and burning process especially during ignition delay period.

Crude palm oil (CPO) and straight vegetable oil (SVO) have considerably renewable, higher viscosity and density, non-toxic, less sulphur and aromatic contents compared to diesel fuel. These biodegradable fuels are also easily produced and become more attractive because of the benefit to environment. Biodiesel derived by CPO has the similar physical fuel properties with diesel fuels in terms of cetane number, heat of vaporization, stoichiometric air/fuel ratio and can reduce the HC, CO, and PM which directly causes less greenhouse gas emissions. On the other hand, SVO which refer to wide class of vegetable oil such as soybean oil, sunflower oil and palm oil, but in characteristic it would be a large differs. In diesel engine, the relation between mixture formation during the ignition delay period and burning process in diesel combustion that strongly affects the exhaust emissions (Amir *et al.*, 2009; Tanaka *et al.*, 2000). During fuel air mixing, the viscosity of fuels has important effects on the fuel droplet formation, atomization, vaporization and fuel-air-mixing process, which influencing the exhaust emissions and performance parameter of the engine (Ismet Celikten *et al.*, 2012; Amir *et al.*, 2011).

Another issue that is particularly critical for use of SVO is fuel viscosity due to biodiesel fuels have faced a problem where the fuels are not operating effectively in cold weather. It is due to the fuel properties such as viscosity that affected the fuels flow rate and poor fuel atomization during combustion process (Azwan *et al.*,

Corresponding Author: Amir Khalid, Department of Plant and Automotive Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400 Johor, Malaysia.
E-mail: amirk@uthm.edu.my

2011; Carraretto *et al.*, 2004; Sonune *et al.*, 2012). Viscosity will gradually decrease as the temperature increase and it will influence the fuel-air mixing due to the changes of spray evaporation and consequently influence the combustion, performance and emissions of diesel engine. In addition, the use of vegetable oils or its blends (higher viscosity) without preheat effects on fuel droplet formation, poor atomization, vaporization and air fuel mixing process (Abdullah Adam *et al.*, 2012; Anja *et al.*, 1999). These effects cause important engine failures such as fuel filter clogging, piston ring sticking, injector choking, carbon formation deposits and rapid deterioration of lubricating oil leads to high smoke, HC and CO emissions (Wira Jazair *et al.*, 2011; Aziz *et al.*, 2006). In addition, increasing fuel temperature or heating also will ease the problem of injection process because it results in a decrease of the arithmetic diameter of the fuel droplets due to the effect of surface tension and viscosity changes with temperature thus improving the spray formation and combustion process. Nandkishore *et al.*, (2012) concluded that fuel properties is one of the significant that affecting the engine compression successful utilization of biodiesel blends as substitute to fuel requires a high knowledge on the properties blends which is the initial state of combustion in a diesel engine. The vegetable oils were all extremely viscous with viscosities ranging 10–20 times greater than standard diesel fuel although high acid value. SVO blending with commercial diesel has improves the cold flow performance and considerably reduces smoke emission. The reduced smoke may be expected to allow an expansion in the exhaust gas recirculation (EGR) limit and lead to reduced oxides of nitrogen (NO_x) production (Vijay *et al.*, 2013). In addition, G Lakshmi Narayana Rao, *et al.*, 2008 found that the cetane number of a fuel, which indicates the self-igniting capability, has a direct impact on ignition delay. Higher NOX emissions occur with SVO, at the maximum load the substantial difference being observed, this pattern, different from CO, is probably not only due to a lower atomization quality. In fact, the increment is lower than nominal condition at lower load, which is the opposite of the CO trend. The increase of NOX emissions at higher combustion temperatures is a well known trend but it cannot by itself explain the increase in NOX, as a lower thermal release can be expected for SVO combustion (Wira Jazair, *et al.*, 2011).

This research investigate the effects of CPO biodiesel fuel and SVO together with engine speed and variant load conditions on the combustion process, combustion characteristics, exhaust emissions and engine performance. In this study, biodiesel from CPO has been blended and preheated before going through properties and performances test to analyze the quality of CPO biodiesel blend as an ignition fuel. The preheated biodiesel (40°C, 50°C and 60°C) was tested in diesel engine at three different biodiesel ratios which are B5, B10 and B15. To make further analysis for this study, diesel fuel also has been tested to make the comparison between diesel fuels and preheated biodiesel result. The performance parameters consist of brake power (BP), torque and flywheel torque. For the engine emission, the properties that being tested consist of hydrocarbon (HC), oxygen (O₂), carbon dioxide (CO₂), carbon monoxide (CO), nitrogen oxide (NO_x) and smoke opacity. It is expected that this work will provide the knowledge of the effects of fuel properties due to the variant in biodiesel blending ratio on combustion characteristics, emissions and performance.

Experimentation:

Material Preparation – In this research the biodiesel and straight vegetable oil (SVO) used are derived from Crude Palm oil (CPO) biodiesel. Biodiesel which provided by Universiti Tun Hussein Onn Malaysia (UTHM) biodiesel pilot-plant and straight vegetable oil (SVO) produced by SAJI brand. Three kinds of the fuels tested were blends with the diesel grade II diesel (STD) for biodiesel and SVO are B5(5%vol), B10(10%vol), B15(15%vol) and S5(5%vol), S10(10%vol) and S15(15%vol), respectively. The biodiesel blending ratio is referring to the percentage mixture volume diesel and biodiesel according to the weight. 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.

In particular the fuels were tested is commercial diesel and blends of vegetable oil with ratio vegetable palm oil with diesel. The standard diesel (OD) was purchased at the commercial pump station and the blending process was done in our automotive laboratory by standard methods. The results for all the BDF conditions were compared with baseline operating conditions of standard diesel (STD). The temperature of blending process will be set at 60°C and the ratio mixture will stirred at constant speed at 270 rpm, the timing of the blending process will be set for 60 minutes. Fig. 1 below is the blending machine block diagram use to produce the biodiesel mixture. Table 1 summarizes the comparison fuel properties characteristics of the standard fuel diesel (STD) and blending ratio biodiesel. The properties test for all types of fuel covers density, kinematics viscosity, flash point, water content and acid value. In this research, the kinematic viscosity and density properties of palm oil blend were measured by Viscolite 700 model VL700-T15 and Metter Toledo Diamond Scale modeled JB703-C/A, respectively. The water content was measured using Volumetric KF Titrator model v20 and the flash point measured by Pensky-Martens PMA 4. The schematic arrangement of experimental set up including the preheat tank are shown in Figure 2. The preheat fuel tank of the oil blends was accomplished by a new develop tank

attached to the engine. Preheat tank was used to preheat the biodiesel blends ratio according to the temperature of 50°C.

Table 1: Properties of SVO and standard diesel.

Fuel types	Properties				
	Density (g/cm ³)	Kinematics Viscosity (cp)	Flash Point (°C)	Water Content (ppm)	Acid Value (mg KOH/g)
STD	0.83374	3	80	79.6	0.423
S5	848.734	3.5	83	173.2	0.20378
S10	852.457	3.9	84	195.9	0.24694
S15	852.764	5	90	194.6	0.24933

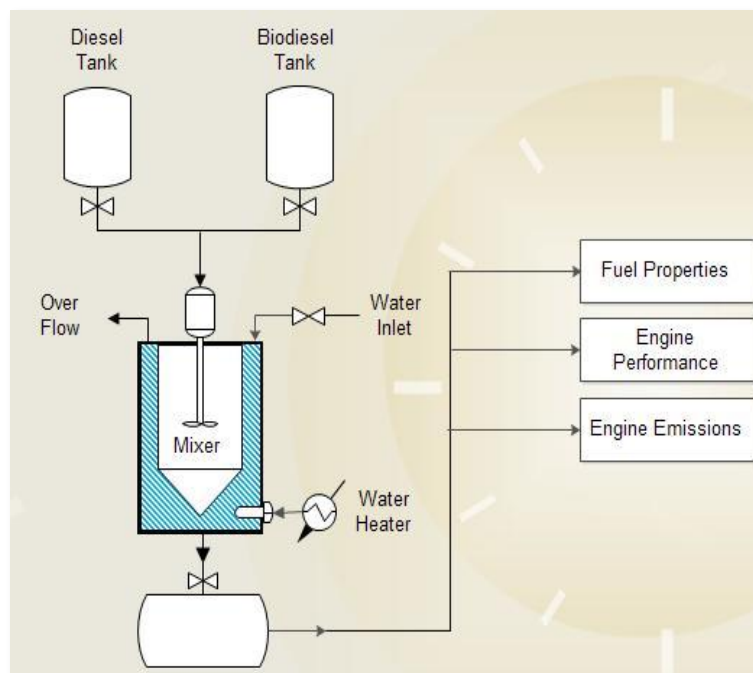


Fig. 1: Blending process of producing SVO blended fuel.

Table 2: Engine specification.

Engine	Mitsubishi
Model Code	S-L049GV-NTD
Engine Model	4D56 (turbocharger)
Engine type	Serial 4 cylinder OHC turbo
Fuel type	Diesel
Fuel system	Distribution type jet pump
Bore/stroke (mm)	91.1/ 95
Maximum power	85 ps (62.52 kw) / 4200 rpm
Maximum Torque	20.0kg-m(196 N-m)/2000rpm
Displacement	2476 cc
Compression Ratio	21.0
Supercharger	TURBO
Vehicle Weight	1590 kg

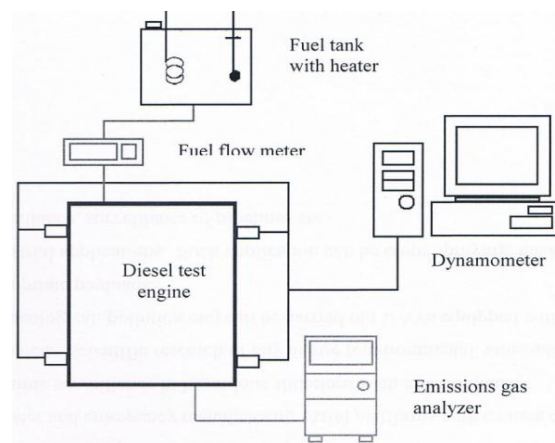


Fig. 2: Experimental set up.

The details of engine test specification are given in Table 2. A series of measurements were conducted on a test commercial vehicle (Mitsubishi Pajero) intended for automotive application. The experimental program was carried out using the commercial vehicle of four-cylinder four stroke-cycle DI diesel engine (Mitsubishi S-L049GV-NTD). The engine is equipped with turbocharged with maximum power of 62.52 kW (4200 rpm) and compression ratio of 21:1. The engine fuel consumption was measured using a precision ONOSOKKI volumetric fuel flow meter, and are pegged between the preheat fuel tank and the fuel pump. The engine was loaded by Dynapack Chassis Dynamometer Machine model 4022. The engine speed was adjusted at variant of 1500, 2000, 2500 and 3000 rpm. The chassis dynamometer unit loads was held fixed at high 100% thus covering the typical and high load operation of the combustion regime. The vehicle performance data comprised power (kW), flywheel torque (Nm) together with the exhaust emissions measurements. Autocheck 5-Channel Gas Emission Analyzer is used to determine the emissions of the engine such as carbon monoxide, carbon dioxide and oxygen from exhaust. Smoke emission was measured by Autocheck Smoke Opacity Meter and opacity range 0~100%. Dragger MSI EM200-E was used to measure the differential pressure, temperature and a wide range of gas concentration with high precision.

RESULT AND DISCUSSION

The effects of preheat blending ratio of straight vegetable oil (SVO) on performance and emissions was investigated at the base standard diesel (STD), S5(5% vol), S10(10% vol), and S15(15% vol) for engine speed of 1500, 2000, 2500 and 3000 rpm. The engine was operated under 0 % and 50% load operations. Figure 3 depicts the variation in combustion emission characteristics as blending ratio of SVO is varied. The graph illustrates the emissions of CO, O₂, opacity, CO₂, HC and NO_x against engine speed. As seen in Fig. 3, increased of SVO blending ratio, increase the NO_x emission. However, increasing blending ratio will decrease the value of HC and smoke opacity.

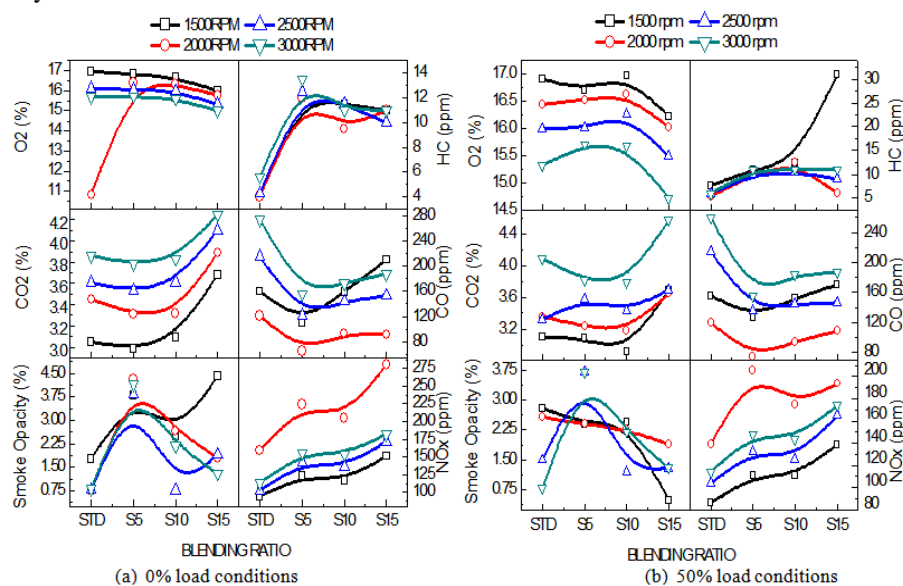


Fig. 3: Effects SVO blends and engine speed on emissions.

On the other hand the increasing of SVO blending ratio will decrease the emission value of Oxygen (O₂), the lowest O₂ value is at 3000 rpm. There is small range of difference value for CO₂ between the blending ratios. For CO emission the lowest value is at S5 blending ratio, however other ratio is still lower compare to standard diesel (STD). In addition, increasing of SVO blends the NO_x emission is getting higher and the highest is at S15 blending ratio and the graph demonstrates the highest NO_x is at 2000 rpm but decrease as engine speed increase. For CO emission characteristic the lowest CO value is at S5 blending ratio, it is compared to variant engine load and engine speed. However for HC the SVO blends indicates the higher value compared to standard diesel and as the load increase the HC emission also rises, the highest HC emission is at 100% load at 3000 rpm. This behavior may attributes from the poor fuel-air mixing due to the increasing of fuel viscosity and thus influences to the poor combustible mixture and lower heating value in vegetable oil which resulting the lower temperatures. On the other hand, NO_x production is quite similar under without load condition and rapidly increases during 100% load condition and engine speed 200 rpm. It seems that the increasing of fuel quantity influences the increasing oxygenated fuel and promotes the high combustion temperature thus predominantly effects the increasing of NO_x production.

Figure 4 shows the effects of engine performance as blending ratio of SVO is varied under 0% and 50% load conditions. The flywheel torque, brake power and torque were obtained directly from chassis dynamometer. As seen in Figure 4, under without load conditions, increase the engine speed will effects the increase of fly wheel torque, torque and brake power, more rapidly highest torque at 3000 rpm with standard diesel (STD) fuel. In addition, it also observed that the brake specific fuel consumption (BSFC) of straight vegetable oil blends is higher compare to the standard diesel, and the highest value at 0% load at blending ratio S5 at engine speed 2000 rpm. BSFC has correlation with the loads and at higher speeds more fuel is consumed to generate the equal power and the engine consumes almost the same amount of fuel to generate power for all three speeds. The variation of BSFC demonstrates that S5 blending ratio has the highest value at 2000 rpm, it may due to low cylinder pressure at low speed is somewhat greater than the higher speed. On the other hand, fly wheel torque and torque in high engine speed which is at 3000 rpm decrease with the increasing blending ratio due to high viscosity will increase the mixture momentum and consequently penetration in the cylinder.

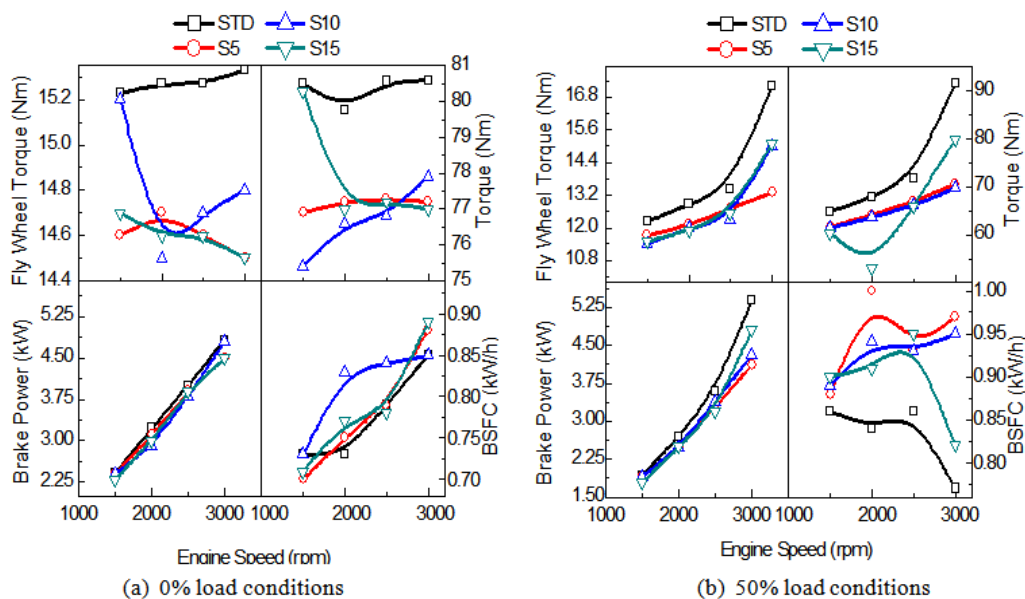


Fig. 4: Effects SVO blends and engine speed on performance.

The effects of preheat blending ratio of preheated biodiesel (B5) and SVO (S5) on performance were investigated at the base standard diesel (ND) and B5 without preheat (NB5), B5 with preheat (PB5), SVO without preheat (NS5) and SVO with preheat (PS5) for preheat biodiesel of 50°C for engine speed of 1500, 2000, 2500 and 3000 rpm. The variations of engine performance with engine speed and preheat of fuel under 0% and 50% load operations are shown in Fig. 5. As seen in Fig. 5, the brake power increase with the increasing of engine speed and happens for all load conditions. It was observed that the increasing preheat fuel under high load condition produced more torque and with the little change of the brake power increases.

Next, the effects of preheat blending ratio of preheated biodiesel under high blending ratio of (B15) and SVO (S15) on performance. The effects of high blending ratio of fuel were investigated in a manner similar to that employed to study the lower of blending ratio. The variations of engine performance with engine speed and preheat of high blending ratio under 0% and 50% load operations are shown in Fig. 6. Under high blending ratio and high load condition, the SVO fuel influences the reduction of torque and brake power compared to the

preheat biodiesel (B15) condition. It seems that the increasing of SVO fuel temperature is not great influences on the fuel viscosity thus effect to the engine performance. This may be attributed to complete combustion because of the preheated will improves the fuel-air mixing due to the changes of viscosity of fuel.

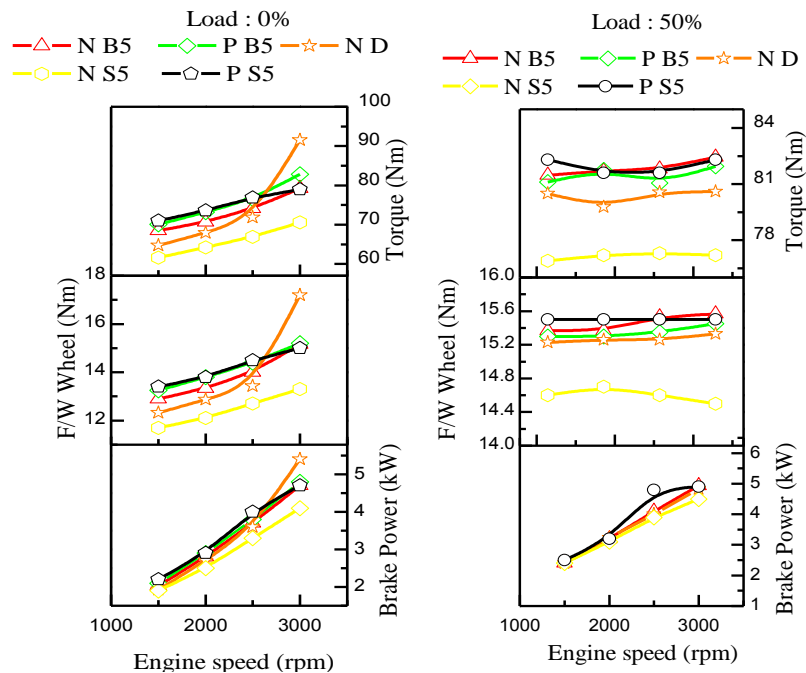


Fig. 5: Effects preheated B5 biodiesel (CPO) and SVO blends with different load condition on performance.

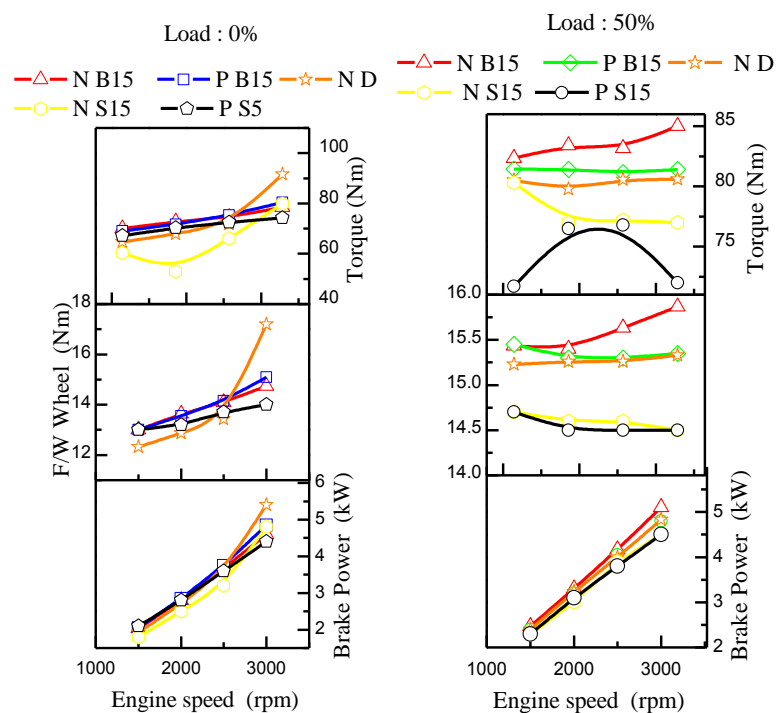


Fig. 6: Effects of preheated high blending ratio of biodiesel (CPO) and SVO blends with different load condition on performance.

This section investigated the effects of variant blending ratio and preheated (B5, B15) and SVO (S5, S15) fuel on exhaust emission, without preheat fuel blends of B5 (NB5) and N (S5) were employed as a base condition. Figure 7 and Figure 8 depict the variation in the emissions such as smoke opacity, HC, O₂, CO, CO₂ and NO_x with different engine speed, fuel temperature and variant blending percentage. As seen in Fig. 7, the

implementation of biodiesel and SVO influences the increasing of CO and CO₂ emission with the increasing of the RPM, more rapidly during 3000 rpm. However, the HC production is lower under the biodiesel combustion especially under 2000 rpm. It also shows the highest HC emission during the NS5. It seems that increasing of the blending ratio for SVO will weaken the fuel ignitability due to the high viscosity influences and poor fuel-air mixing. This circumstance result in lower combustion pressure and temperature thus increases HC emissions and smoke opacity.

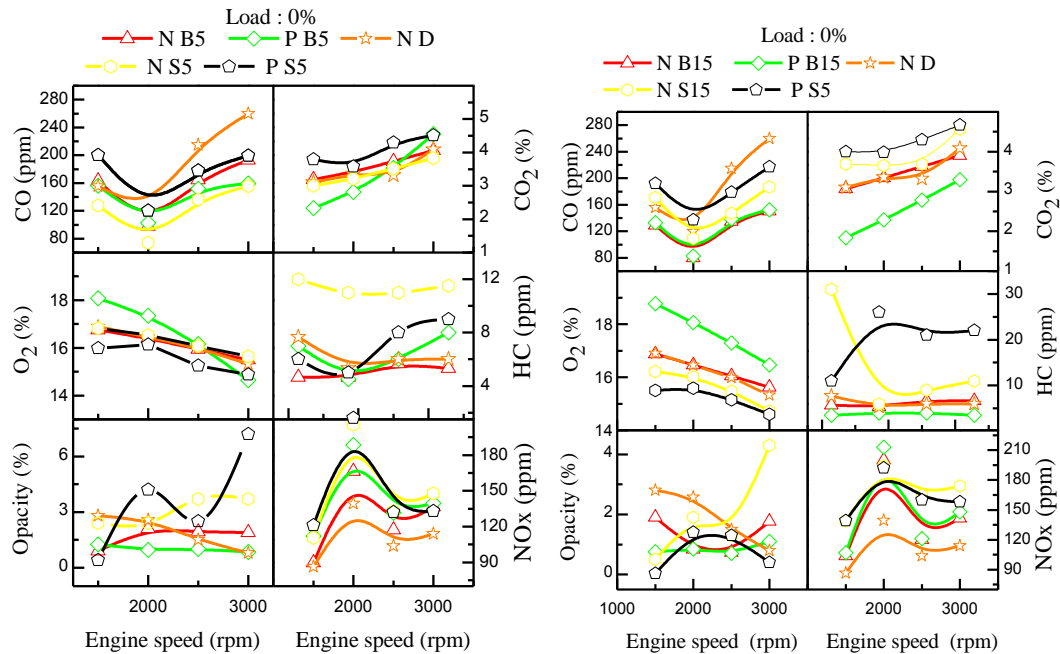


Fig. 7: Effects preheated biodiesel (CPO) and SVO blends on emissions under 0% load conditions.

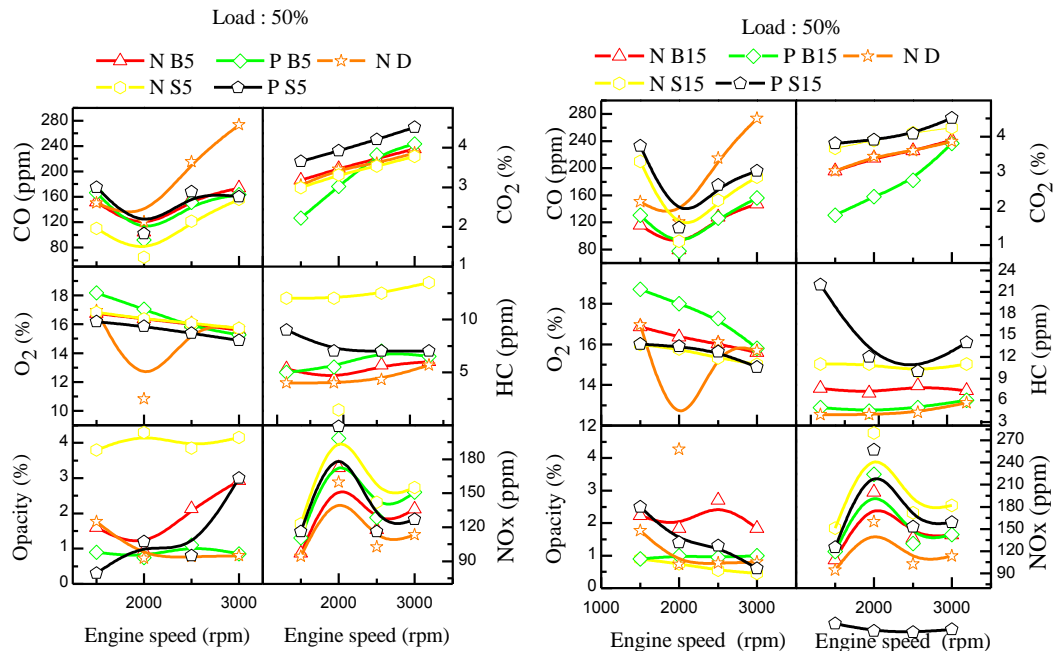


Fig. 8: Effects preheated biodiesel (CPO) and SVO blends on emissions under 50% load conditions.

The effects of preheat blending ratio of biodiesel and SVO under high load conditions on emissions was investigated at the base standard diesel (ND) for engine speed of 1500, 2000, 2500 and 3000 rpm. The engine was operated under 50% load operations. Figure 8 depicts the variation in combustion emission characteristics as preheat temperature both fuel is varied. As seen in Fig. 8, increased preheat fuel temperature thus predominantly influences the reduction of CO and CO₂, while having big impact on the increasing of NOx and more higher under NS5 and NS15 especially at 2000 rpm. It seems that the low viscosity of fuel due to the

higher fuel preheat enhanced the fuel-air premixing thus influences the higher NO_x. This behavior could be associated with the better combustible mixture preparation and higher oxygen content in high blending ratio of NS5 and NS15 thus influences on combustion process.

Conclusion:

Engine performance and emissions results of preheat blending ratio of biodiesel (BDF) and straight vegetable oil (SVO) derived from oil palm under variant in engine speed and load conditions were compared with the results obtained with standard diesel and without preheat. The results of the study may be summarized as follows:

1. The engine performance is nearly equal and doesn't vary significantly with the changes of the SVO blending ratio for all load conditions.
2. The production of NO_x did not show any improvement when using preheated CPO biodiesel fuel, while having big impact on the increasing of NO_x and higher under high blending ratio of SVO. However, preheated CPO biodiesel and SVO fuel reduces CO and CO₂ emissions as compared to the standard diesel.

ACKNOWLEDGEMENTS

The authors also would like to thank the Universiti Tun Hussein Onn Malaysia and Ministry of Higher Education, Malaysia for supporting this research under COE-MTUN Grant Scheme VOT.C009 and Fundamental Research Grant Scheme (FRGS) vot.1054.

REFERENCES

- Amir Khalid, Tomoaki Yatsufusa, Takayuki Miyamoto, Jun Kawakami, Yoshiyuki Kidoguchi, 2009. Analysis of Relation between Mixture Formation during Ignition Delay Period and Burning Process in Diesel Combustion, Small Engine Technology Conference 2009 (SETC2009), SAE Paper No. 2009-32-0018.
- Tanaka Kengo, Endo Hiroyuki, Imamichi Akira, Oda Yuji, Takeda Yoshinaka (Mitsubishi Mot. Corp.), 2000. Study of Homogeneous Charge Compression Ignition Using a Rapid Compression Machine.
- Ismet Çelikten, Emre Mutlu, Hamit Solmaz, 2012. Variation of performance and emission characteristics of a diesel engine fueled with diesel, rapeseed oil and hazelnut oil methyl ester blends, Department of Automotive Engineering, Faculty of Technology, Gazi University, Teknikokullar, Turkey.
- Amir Khalid, Keisuke Hayashi, Yoshiyuki Kidoguchi, Tomoaki Yatsufusa, 2011. Effect of Air Entrainment and Oxygen Concentration on Endothermic and Heat Recovery Process of Diesel Ignition. 2011 SAE/JSAE International Powertrains, SAE Paper No. 2011-01-1834, Fuels and Lubrications Meeting.
- Carraretto, C., A. Macor, A. Mirandola, A. Stoppato, S. Tonon, 2004. Biodiesel as a alternative fuel: Experimental analysis and energetic evaluations. *Energy*, 29: 2195-2211.
- Azwan Sapit, Sho Nagayasu, Yasunori Tsuboi, Yuzuru Nada, Yoshiyuki Kidoguchi, 2011. A Study on Improvement of Diesel Spray Characteristics Fueled by Rape-seed Oil, SAE Paper No. 2011-32-0561.
- Sonune, P.P., H.S. Farkade, 2012. Performance and Emissions of CI Engine Fuelled With Preheated Vegetable Oil and Its Blends. *International Journal of Engineering and Innovative Technology (IJEIT)*, 2(3).
- Abdullah Adam, Mamat Rizalman, Nur Atiqah, Yoshiyuki Kidoguchi and Azran Zafri, 2012. Analysis of Straight Vegetable Oil (SVO) Characteristics at End of Injection (EOI). *Journal of Medical and Bioengineering (JOMB)*, 1(1).
- Anja Oasmaa, Stefan Czernik, 1999. Fuel Oil Quality of Biomass Pyrolysis Oils – State of the Art for the End User. *Energy and Fuel*, 13: 914-921.
- Wira Jazair, Syunsuke Kubo, Masazumi Takayasu, Tomoaki Yatsufusa and Yoshiyuki Kidoguchi, 2011. Performance and Emission Characteristics of a Diesel Engine Fueled by Rapeseed Oil Bio-Fuel. *Jurnal Mekanikal*.
- Aziz, A.A., M.F. Said, M.A. Awang and M. Said, 2006. The Effects of Naturalized Palm Oil Methyl Esters (NPOME) on Performance and Emission of a direct Injection Diesel Engine, The 1st International Conference on Natural Resources Engineering and Technology INRET.
- Nandkishore, Rao, B. Sudheer Premkumar and M. Yohan, 2013. Performance And Emission Characteristics Of Straight Vegetable Oil-Ethanol Emulsion, Department of Automobile Engineering, Guru Nanak Dev Engineering College, Bidar, Karnataka, India, 33: 32-39.
- Vijay Sisarwal, Dr. A.C. Tiwari, 2013. Experimental Investigation of Effect of Straight Vegetable Oil Fuel on Engine Performance Parameters. *International Journal of Engineering Research and Applications*.
- Lakshmi Narayana Rao, G., S. Sampath, K. Rajagopal, 2008. Experimental Studies on the Combustion and Emission Characteristics of a Diesel Engine Fuelled with Used Cooking Oil Methyl Ester and its Diesel Blends. *International Journal of Engineering and Applied Sciences* 3.