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Preheated Biodiesel Derived from Vegetable oil on Performance and Emissions of Diesel Engines: A Review

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Abstract. This present study discusses the effects of preheated biodiesel and its blends on the performance and emissions of diesel engines. Limited supply of fossil fuel makes biodiesel as one of the major solution for this current situation. However, in using biodiesel and its blends as fuel had created few problems such as poor fuel droplet formation and atomization that consequently result on lots of carbon formation deposit on the valves and injector choking. These problems occur due to the effect of higher viscosity of the biodiesel and its blends itself. This paper reviews the recent research on the effects of preheated biodiesel on viscosity and thus influences to the performance and emissions. Generally there are four methods to lower the viscosity that are heating, blending, micro-emulsification and transesterification. Heating is the easiest solution to bring lower the viscosity. Biodiesel and its blends were heated up before combustion process and most of the researcher reported that the brake power was lower than diesel fuel but higher than unheated biodiesel while the BSFC was found to be higher than diesel fuel and unheated biodiesel. In addition, it observed that the NO_x emission was higher than that of diesel fuel and unheated biodiesel.

Introduction

Biodiesel is known as a non-petroleum diesel, a mixture of mono-alkyl esters of long chain fatty acid (FAMEs) and it is an alternative fuel that made from vegetable oils and animal fats. It is a renewable energy, more cleanly than petroleum fuel and large availability sources [1-4]. The concern about biodiesel is quickly increased since the petroleum crises in 1970s that cause rapidly increasing in market prices. Growing concern of the environment and the effect of greenhouse gases also had revived more and more interests in the use of vegetable oils as a substitute of petroleum fuel [3,5]. Properties of biodiesel generally has higher density, viscosity, cloud point, cetane number, lower volatility and heating value compared to diesel fuel that affecting on the engine performance and emissions. However, neat biodiesel or its blends may be used in the existing diesel engines with little or no modification to the engine [6-10].

The influences of biodiesel viscosity on combustion process

In the era of improvement technologies, emission regulations have become more stringent in order to keep and maintain clean and healthy environment. Industrial revolution especially in automotive industry was contributing quite higher number of percentage to the earth pollutions in our daily life that consequently will contribute to global warming effects and acid rain formation. Despite years of improvement on the petroleum fuels and combustion characteristics were attempts, issues regarding emissions still become the main conversation in the automotive industry. Limited supply of world petroleum resources and unpredicted increment on the petroleum price made the situation more critical. Thus, demand on the utilization of biodiesel fuels and its blends as alternative energy sources is urgently required to meet the future legislation. However, lots of researchers have reported that use of biodiesel or its blends effects on fuel droplet formation, poor atomization, vaporization and air fuel mixing process due to its higher viscosity [12-16]. 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 [13-16]. High viscosity fuel also leads to high smoke, HC and CO emissions [12]. There are several technique for reducing viscosity; heating or pyrolysis, blending or dilution, micro-emulsification and transesterification [13,17-18]. Viscosity will gradually decrease with the increase of preheating temperature. 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 [19]. Thus, it gives better spray formation and combustion process.

The effects of preheat biodiesel on performance

The performance parameters of preheated biodiesel had been reviewed such as brake thermal efficiency, BSFC and brake power. The parameters were evaluated and compared to the neat diesel fuel.

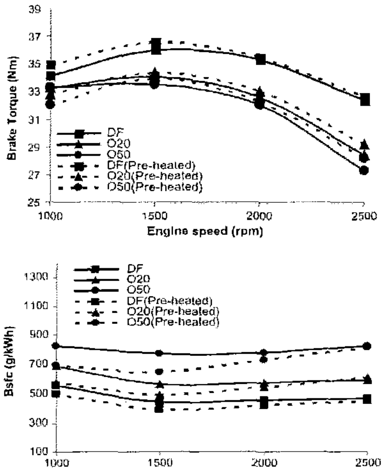

Figure 1: Performance parameters of rapeseed oil biodiesel [12]

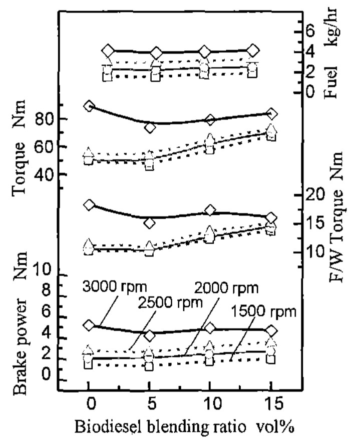

Figure 2: Effects of palm oil blending on engine performance analysis without load conditions [4]

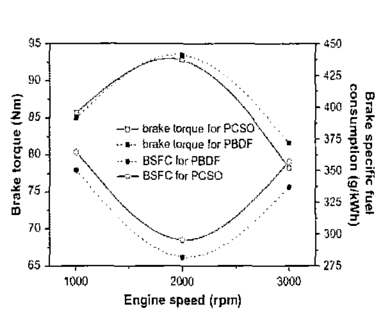

Figure 3: The brake torque and BSFC vs engine speed of preheated crude sunflower oil [20]

Agrawal et al. [17] studied the performance of a four stroke single cylinder diesel engine fuelled by preheated jatropha oil as fuel. They reported that the BSFC of preheated jatropha oil was higher than that of diesel fuel but lower that unheated jatropha oil at medium load. Moreover, the thermal efficiency of preheated jatropha oil was lower that diesel fuel but slightly higher than unheated jatropha oil. The reason for this behavior may be improved fuel atomization because of reduced fuel viscosity. The use of preheated rapseed oil biodiesel at two different fuel blends: O20 (20% rapeseed oil; 80% diesel fuel) and O50 (20% rapeseed oil; 80% diesel fuel) was investigated by Hazar et al. [12]. They found that preheated biodiesel has increased the brake torque from its normal condition but the value remained lower when compared with that diesel fuel as per depicted in Figure 1 and Figure 2 as a reference for standard biodiesel. Meanwhile, the power variation of diesel fuel is higher than those of O20 and O50 for all engine operations either with preheat or not because diesel fuel has higher calorific value. The increment of rapeseed oil in the blends remained lower compared to diesel fuel because the viscosity of the blend is reducing with preheating led to the higher leakages in the pump and injector resulting in lower power outputs. The BSFC was increased with the increasing rapeseed oil in the blends when compared with diesel fuel. Karabektas et al. [13] analyzed the preheated cottonseed methyl ester performance on a diesel engine and concluded that the brake power of the heated fuel was lower than that of diesel fuel due to an excessive leakage through the fuel pump and injectors. However, thermal efficiency was higher compared to diesel fuel and they reported it was attributed to the preheating process that gives better combustion characteristics of biodiesel because of decreased viscosity and improved volatility.

Pugazhvadivu et al. [14] investigated the performance of a diesel engine using preheated waste frying oil as fuel. They reported that thermal efficiency was lower compared to diesel fuel. Singh et al. [18] studied the performance of preheated jatropha oil on medium capacity diesel engine. They found that the brake thermal efficiency for jatropha oil was lower than diesel fuel throughout the entire operating range. However, when the temperature of preheating fuel increases, brake thermal efficiency also increases close to diesel fuel. The reason why the brake thermal efficiency lowers compared to diesel fuel are lower calorific values due to presence of O_2 in unsaturated hydrocarbon and high viscosity of jatropha oil. Canaki et al. [20] tested an indirect injection of four strokes diesel engine using preheated crude sunflower oil. Their tests showed that the brake torque decreased by 1.36% while the BSFC increased by almost 5% on average compared to diesel fuel over the speed range at full load condition as per depicted in Figure 3. The effects of preheated cottonseed oil methyl ester on performance parameters were conducted by Augustine et al. [21] using 660CC single cylinder diesel engine. They concluded that BSFC is higher than that of diesel engine for all loads tested. This was due to more blended fuel which is used to produce same power as compared to diesel fuel. Moreover, brake thermal efficiency was lower than diesel fuel but increased by the preheated temperature ranging from 40°C up to 80°C, but for 100°C decreases due to vapor locking in the fuel line and hence more fuel consumption is obtained for the same power compared to other mode of operation. Hossain and Davies [21] investigated the performance an indirect injection multi-cylinder compression ignition operating on preheated jatropha and kranja oils. The authors reported that BSFC of jatropha and kanja oils were higher as compared to diesel fuel because the calorific value for both oils was lower than diesel fuel thus more fuel is needed for the same engine output. Yilmaz and Morton [23] studied the performance of three vegetable oils at two different engines; Yanmar and Kubota engines. They found that preheating increases thermal efficiency and vegetable oil shows higher thermal efficiencies than diesel fuel for all of the preheated fuels and both engines. The potential waste cooking oil biodiesel as an alternative fuel was investigated by Licauco and Biona [24]. They tested the fuel on Mazda 4bc2 engine and found that the power produced was lower than diesel fuel due to its lower cetane number and heating value. Meanwhile the BSFC was averagely 19% higher compared to diesel fuel.

The effects of preheat biodiesel on emissions

Emissions from combustion of biodiesel and its blends generally similar to combustion of diesel fuel such as CO, CO_2, NO_x, smoke, unburned HC and sulphur oxides. A review has been made about preheat biodiesel emissions.

Agrawal et al. [17] conducted an experiment of preheated jatropha oil in a direct injection compression ignition engine. They observed that heating the oil result in marginal increase of CO_2 emission compared to diesel fuel but lower than unheated jatropha oil. They also observed that CO emission has similar trend to the CO_2 emission. This possibly attributed to poor spray atomization and non-uniform mixture formation. Meanwhile, HC emission was lower at half load and tends to increase at higher load for all fuels. Hazar et al. [12] reported reduction in smoke and CO emissions with the induction of preheat fuel before combustion. This trend may be due to the higher viscosity and poor volatility which causes poor spray characteristics, forming locally rich air-fuel mixture during combustion process. The NO_x emission increases with the increase in fuel inlet temperature. The increase in NO_x with preheating emission was attributed to the increase in combustion gas temperature. CO emissions lower in comparison to diesel fuel while running the diesel engine using cottonseed oil methyl ester. Preheating of biodiesel decreases the viscosity and improves the oxidation of biodiesel in the cylinder. The NO_x emission was higher than diesel fuel and the authors found that the maximum increase was obtained in the case of preheating temperature was 90°C [13-15]. Mamat et al. [19] investigated the emissions of rapeseed methyl ester on V6 Twin VG Turbo diesel engine. They found that the NO_x emission was higher than diesel fuel for both with and without exhaust gas recirculation system. However, CO and unburned HC emissions were found lower for the combustion with exhaust gas recirculation and higher without exhaust gas recirculation. In addition, the preheated jatropha oil and preheated crude palm oil lowering the CO_2 emission, CO and unburned HC emissions of diesel fuel due to vegetable oil contains O_2 element and carbon content is relatively lower in the same volume of fuel consumed at the same engine load [16,18].

Preheated crude sunflower oil produced lower CO_2, unburned HC and smoke emissions compared to diesel fuel had been reported by Canaki et al. [20]. However, CO emission of preheated crude sunflower oil was higher at low engine speed and becomes lower when the engine speed exceeds 2400rpm. Augustine et al. [21] observed that when preheated cottonseed oil methyl ester was used as fuel in the direct injection diesel engine, the CO, unburned HC and smoke produced were lower compared to diesel fuel. This were attributed to the higher O_2 content of biodiesel which could improve the combustion process and heating process decreases the viscosity of biodiesel, thus improves the oxidation of biodiesel in the cylinder. However, preheated cottonseed oil methyl ester yields higher NO_x emission at all loads than that of diesel fuel. Hossain and Davies [22] investigated the effects of jatropha and kranja oils at Lister Petter diesel engine. At low loads, CO and CO_2 emissions were almost the same for all fuels and at higher loads, diesel emissions were lower compared to jatropha and kranja oils. However, NO_x emission was higher for both fuels while O_2 produced was lower than that of diesel fuel. Emissions of two different engines were studied by Yilmaz and Morton [23]. The authors found that the CO and NO emissions were higher for both engines compared to the diesel fuel. This was attributed to the poor spray atomization and non-uniform mixture formation. However, the unburned HC was lower at low load and it's close to diesel fuel emission when the load increased. Kumar et al. [25] tested preheated animal fat and observed the smoke and NO emissions were lower while unburned HC and CO emissions were higher compared to diesel fuel. The result of low smoke levels is explained by the presence of fixed carbon in the animal fat. Lim et al. [26] observed that preheated crude palm oil combustion produced about 2.8% more CO emission than diesel fuel combustion meanwhile, the NO_x emission for preheated crude palm oil was higher than that for diesel fuel by 25.7% [27-30].

Conclusions

The higher viscosity of biodiesel and its blends can be solving by preheating the fuel before combustion. Preheat biodiesel and its blends were results in a better fuel consumption and thermal efficiency produced due to decrease of the arithmetic diameter of the fuel droplets. In addition, this effect also contributes from the surface tension and viscosity changes with temperature [19]. Generally, emissions produced was lower for CO, CO_2, HC and smoke. CO emissions was reduced due to few reasons; high O_2 content that could promotes better combustion process and heating effect that lower the viscosity and consequently improves the oxidation of biodiesel in the cylinder [13,21]. Meanwhile, the NO_x production was observed higher for the preheated fuel due to improved spray characterictics, better combustion due to high O_2 content and higher gas temperature in the cylinder as a results of increase in fuel inlet temperature.

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References

[1] Mekhilef, S., Siga, S., & Saidur, R. (2011). A review on palm oil biodiesel as a source of renewable fuel. Renewable and Sustainable Energy Reviews, 15(4), 1937–1949.

[2] Abdullah, A. Z., Salamatinia, B., Mootabadi, H., & Bhatia, S. (2009). Current status and policies on biodiesel industry in Malaysia as the world's leading producer of palm oil. Energy Policy, 37(12), 5440–5448.

[3] Ehsan, S., & Wahid, M. A. (2012). Necessity of biodiesel utilization as a source of renewable energy in Malaysia. Renewable and Sustainable Energy Reviews, 16(8), 5732–5740.

[4] 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", International Conference on Mechanical & Manufacturing Engineering (ICME2012), pp.1-5, 2012.

[5] Balat, M., & Balat, H. (2008). A critical review of bio-diesel as a vehicular fuel, Energy Conversion and Management, 49, 2727–2741.
[6] Benjumea, P., & Agudelo, J. (2008). Basic properties of palm oil biodiesel – diesel blends, Fuel, 87, 2069–2075.
[7] Amir Khalid, Tomoaki Yatsufusa, Takayuki Miyamoto, Jun Kawakami, Yoshiyuki Kidoguchi, "Analysis of Relation between Mixture Formation during Ignition Delay Period and Burning Process in Diesel Combustion", Small Engine Technology Conference 2009 (SETC2009); Society of Automotive Engineering (SAE), SAE Technical Papers No. 2009-32-0018, 2009
[8] Deepanraj, B., Dhanesh, C., Senthil, R., Kannan, M., Santhoshkumar, A., Lawrence, P. (2011). Use of Palm oil Biodiesel Blends as a Fuel for Compression Ignition Engine. American Journal of Applied Sciences, 8(11), 1154–1158.
[9] Kalam, M. A., Masjuki, H. H., Husnawan, M., & Yamane, K. (2005). Performance Improvement of a Diesel Engine Using Additive in Palm Oil Methyl. JSAE, 1–4.
[10] Lim, S., & Teong, L. K. (2010). Recent trends, opportunities and challenges of biodiesel in Malaysia: An overview. Renewable and Sustainable Energy Reviews, 14, 938–954.
[11] Xue, J., Grift, T. E., & Hansen, A. C. (2011). Effect of biodiesel on engine performances and emissions. Renewable and Sustainable Energy Reviews, 15(2), 1098–1116.
[12] Hazar, H., & Aydin, H. (2010). Performance and emission evaluation of a CI engine fueled with preheated raw rapeseed oil (RRO)–diesel blends. Applied Energy, 87(3), 786–790.
[13] Karabektas, M., Ergen, G., & Hosoz, M. (2008). The effects of preheated cottonseed oil methyl ester on the performance and exhaust emissions of a diesel engine. Applied Thermal Engineering, 28(17-18), 2136–2143.
[14] Pugazhvadivu, M., & Jeyachandran, K. (2005). Investigations on the performance and exhaust emissions of a diesel engine using preheated waste frying oil as fuel. Renewable Energy, 30(14), 2189–2202.
[15] Khalid, A., and Manshoor, B., "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.
[16] Amir Khalid, "Effect of Ambient Temperature and Oxygen Concentration on Ignition and Combustion Process of Diesel Spray". Asian Journal of Scientific Research, 2013. pp.1-11.
[17] Bari, S., Lim, T. H., & Yu, C. W. (2002). Effects of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine. Renewable Energy, 27(3), 339–351.
[18] Kalam, M. A., & Masjuki, H. H. (2005). Emissions and Deposit Characteristics of a Small Diesel Engine When Operated on Preheated Crude Palm Oil. SAE Paper, 2005-01-36
[19] Agarwal, D., & Agarwal, A. K. (2007). Performance and emissions characteristics of Jatropha oil (preheated and blends) in a direct injection compression ignition engine. Applied Thermal Engineering, 27(13), 2314–2323.
[20] Singh, B., Kumar, N., Du, Y., & Bae, K. (2010). Performance and emission study of preheated Jatropha oil on medium capacity diesel engine. Energy, 35(6), 2484–2492.
[21] Mamat, R., Abdullah, N. R., Xu, H., Wyszynski, M. L., & Tsolakis, A. (2009). Effect of Fuel Temperature on Performance and Emissions of a Common Rail Diesel Engine Operating with Rapeseed Methyl Ester (RME). SAE Paper, 2009-01-1896.
[22] Canakci, M., Necati, A., & Turkcan, A. (2009). Combustion analysis of preheated crude sunflower oil in an IDI diesel engine. Biomass and Bioenergy, 33(5), 760–767.
[23] Augustine, A., Marimuthu, L., & Muthusamy, S. (2012). Performance and evaluation of DI diesel engine by using preheated cottonseed oil methyl ester. Procedia Engineering, 38, 779–790.
[24] Hossain, A. K., & Davies, P. A. (2012). Performance, emission and combustion characteristics of an indirect injection (IDI) multi-cylinder compression ignition (CI) engine operating on neat jatropha and karanj oils preheated by jacket water. Biomass and Bioenergy, 44, 1–11.

[25] Yilmaz, N., & Morton, B. (2011). Effects of preheating vegetable oils on performance and emission characteristics of two diesel engines. Biomass and Bioenergy, 35(5), 2028–2033.
[26] Licauco, J. B. M. B. Æ. J. (2009). Performance, smoke characteristics and economics of pre-heated used vegetable oil utilization in Philippine public utility jeepneys. Clean techn Environ Policy, (2009).
[27] Kumar, M. S., Kerihuel, A., Bellettre, J., & Tazerout, M. (2005). Experimental investigations on the use of preheated animal fat as fuel in a compression ignition engine. Renewable Energy, 30, 1443–1456.
[28] Lim, T. H., Bari, S., & Yu, C. W. (2002). Using crude palm oil (CPO) as diesel engine fuel. AJSTD, 19(2), 1–13.
[29] Khalid, A., and Manshoor, B., "Analysis of Mixture formation and Flame Development of Diesel Combustion using a Rapid Compression Machine and Optical Visualization Technique", International Conference on Mechanical & Manufacturing Engineering (ICME2012), pp.1-5, 2012.
[30] Amir Khalid, Keisuke Hayashi, Yoshiyuki Kidoguchi, Tomoaki Yatsufusa, "Effect of Air Entrainment and Oxygen Concentration on Endothermic and Heat Recovery Process of Diesel Ignition", 2011 SAE/JSAE International Powertrains, SAE Technical Papers No. 2011-01-1834, 2011.