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INVESTIGATION OF BLENDED PALM BIODIESEL-DIESEL FUEL PROPERTIES WITH OXYGENATED ADDITIVE

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ABSTRACT

Blended biodiesel fuel is considered as an alternative to current fossil fuels in many applications, at low blending level less than 20% biodiesel. The fuel physical characteristics are among the most important parameter to determine the quality of each fuel. Though biodiesel can replace diesel satisfactorily, problems related to fuel properties persist. In this study diethyl ether (DEE) was used as additive to the palm biodiesel-diesel blended fuel B30 and B40 in the ratios of 2% and 6% by volume and tested for their properties improvement according to ASTM D7467 standard procedures. The tested fuel samples were compared with diesel fuel (D) and palm biodiesel (B100). The minimum pour point for the blended fuel was -7 °C for B30DE6 compared to 14 °C for palm biodiesel, the results shows that the best properties was for B30DE6 where the presence of diethyl ether additive helps to reduce the viscosity by 35%, density by 3.6% and acid value by 57% compared to palm biodiesel. On the other hand, a slight decrease in the energy content has been found with increasing additive and blending portion compared to pure diesel and the lower energy content value was for palm biodiesel. However, the properties of biodiesel and its blended fuel with additive still meet the requirement of ASTM D7467 standards.

Keywords: palm oil biodiesel, blending, diethyl ether, diesel, fuel properties.

INTRODUCTION

Biodiesel have been proposed as an alternative fuel for petroleum diesel in in internal combustion engines (Agarwal 2007; Demirbas 2007; Ramadhas, A.S. Muraleedharan and Jayaraj 2005). It is an alkyl monoester originated from vegetable oils, waste cooking oils or animal fats derived through the transesterification process with the presence of methanol as a catalyst (Obed Majeed Ali *et al*. 2013; Ali *et al*. 2012; Moka *et al*. 2014). In particular, biodiesel has received wide attention as a replacement for diesel fuel because it is biodegradable, nontoxic and can significantly reduce exhaust emissions and overall life cycle emission of carbon oxides (CO_2) from the engine when burned as a fuel. Many investigations have shown that using biodiesel in diesel engines can reduce hydrocarbon (HC), carbon monoxide (CO) and particulate matter (PM) emissions, but nitrogen oxides (NO_x) emission may increase (Agarwal *et al*. 2006; Avinash and Rajamanoharan 2009). The oxygen content of biodiesel is an important factor in the NO_x formation, because it causes to high local temperatures due to excess hydrocarbon oxidation. The increased oxygen levels increase the maximum temperature during the combustion, and increase NO_x formation (Ahmet *et al*. 2009; Raheman and Ghadge 2007). Although the little higher cetane number (shorter ignition delay and so lower temperatures during the premixed combustion phase) and the absence of aromatics tend to contribute to less NO_x production, these factors do not seem to offset the increase caused by the presence of the fuel-bound oxygen even in locally rich zones (Rakopoulos *et al*. 2008).

On the other hand, biodiesel has some disadvantages, such as higher viscosity and pour point, and lower volatility compared with diesel (Ali *et al.* 2015; Ali *et al*. 2014). The poor cold flow property of biodiesel is a barrier to the use of biodiesel diesel blends in cold weather (Sarin *et al*. 2009; Obed M. Ali *et al*. 2013). Diethyl ether might be expected to improve low temperature flow properties as it has a low freezing temperature.

Various researchers tried the blends of DEE with biodiesel to reduce emissions. The addition of DEE with rubber seed biodiesel in lower percentage improved the engine performance and emission characteristics (Ramadhas *et al*. 2008). Similar trend is observed with Karanja oil methyl ester blend, and 15% DEE was the most effective combination (Iranmanesh *et al*. 2008). Likewise, (Sivalakshmi & Balusamy 2010) concluded that 15% DEE is found to be the optimum blend with Jatropha oil methyl ester (JOME) on the basis of performance and emission characteristics. However, (Pugazhvadivu and Rajagopan 2009) found experimentally that 20% of DEE addition was more beneficial in reducing NOx compared to other combination when using Pongamia biodiesel and diethyl ether as fuel. Similarly, (Kannan and Marappan 2010; Kannan and Marappan 2011) agreed in their experimental works that the blending ratio of 20% DEE gives better performance and lesser emissions than other combinations when added to the Thevetia Peruviana biodiesel. On the other hand, (Swaminathan and Sarangan 2012) stated that fish oil biodiesel (BOF), with 2% blend of DEE gave the maximum percentage of reduction of all emission pollutants and suggested as the best option for running the engine with Exhaust gas recirculation (EGR).

In general, biodiesel that originated from palm oil has different properties as compared to other biodiesel made from other organic sources as well as mineral diesel. Palm oil has greater density and viscosity compared to mineral diesel (Pradeep & Sharma 2007). Therefore, a comprehensive data of biodiesel and their blend fuel physical properties is required to analyze the characteristics of biodiesel when operated with conventional diesel engines. The fuel physical properties are very critical parameters in the atomization process in compression ignition engines. Viscosity plays an important role in the atomization quality of fuel injection within the combustion chamber, distribution of fuel droplet size and the uniformity of the mixture. In addition, larger surface tension affects the dissolution of a liquid jet into smaller fuel droplets.

In this study, the fuel characteristics of blended palm biodiesel-diesel fuel with diethyl ether additive are investigated and discussed. These properties provide important data for further investigation of the engine operation with those fuels in terms of performance, combustion and emission characteristics.

RESEARCH METHODOLOGY

Materials and Methods

Palm oil biodiesel (POB) was supplied by local commercial company in Selangor, Malaysia. Diesel fuel was provided by a commercial fuel manufacturer. Samples of palm oil methyl ester and petroleum diesel were prepared through mixing and blending using electrical magnetic stirrer shown in Figure-1. The mixtures were stirred continuously for 20 minutes. Then, diethyl ether (DEE) was added in to blended fuel at low stirring rate (300 RPM). The mixtures were stirred continuously for additional 20 minutes and left for 30 minutes to reach equilibrium at room temperature before they were subjected to any test.

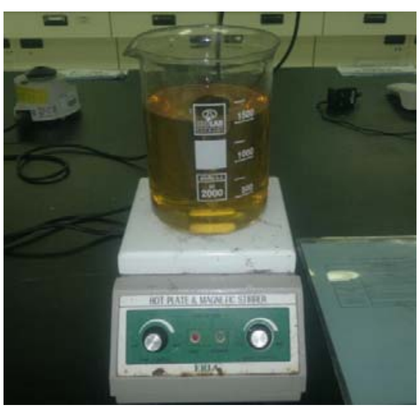

Figure-1. Fuel preparation using magnetic stirrer.

There were eight types of fuel used in the study which includes mineral diesel, biodiesel (B100), blended fuel B30 (30% biodiesel blend with 70% mineral diesel), B30 with 2% DEE (B30DE2), B30 with 6% DEE (B30DE6), blended fuel B40 (40% biodiesel blend with 60% mineral diesel), B40 with 2% DEE (B40DE2) and B40 with 6% DEE (B40DE6). Figure-2 illustrates different analytical apparatus used to measure the fuel properties. All the test methods conform to the ASTM standard procedures for each equipment. The tests were conducted under controlled room temperature, pressure and relative humidity to ensure that the result is not influenced from environmental conditions.

(a)

(b)

(c)

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(d)

(e)

Figure-2. Analytical instruments used to measure fuel properties; (a) Density meter, (b) Viscosity bath, (c) Acid value and acidity tester, (d) Oxygen Bomb Calorimeter, (e) Cloud and Pour Point measuring Equipment.

RESULTS AND ANALYSIS

Viscosity analysis

Viscosity can be defined as the resistance of oil to flow smoothly or the measurement of internal friction. The viscosity of biodiesel is greatly higher compared to mineral diesel, but approximately less than straight vegetable oils. Fuel viscosity can be significantly reduced by using transesterification process. Viscosity has a greater impact under low temperatures that resist the fuel to flow smoothly from the storage tank into the engine. Higher viscosity causes poorer atomization of the fuel spray and inaccurate fuel injectors operation.

Figure-3 shows viscosity of the fuel samples measured using viscosity bath. It clearly shows that the viscosity of B100 is 20% higher than the mineral diesel. This because the free fatty acid (FFA) concentration in biodiesel. However, the viscosity of B30DE6 is recorded as the lowest number at 3.12 mm^2/s which less than the mineral diesel viscosity but still meet the ASTM D7467 requirement. It is clearly obvious that the small amount of diethyl ether diluted in the biodiesel blended fuel is proven to reduce the high viscosity of the fuel. It can be seen from the figure that the viscosity of the blended fuel with an additive is lower than that for diesel fuel.

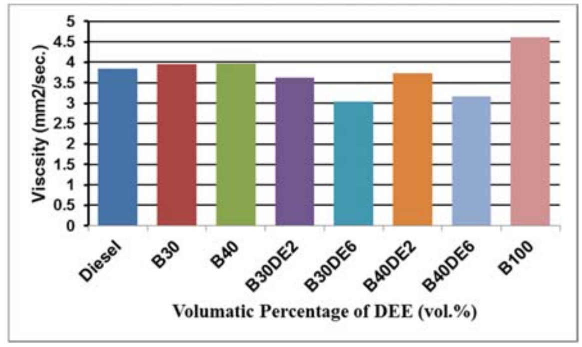

Figure-3. Variation of viscosity.

Density analysis

The lower value of the density is desirable to obtain the maximum engine power through the fuel flow control in the injection pump. It also required minimizing the smoke formation when operates with maximum power (Moraes M. S. A. 2008).

From the test results it is found that the density of the B100 is the highest 881 kg/m^3 as shown in Figure 4. It is clearly shown that the rising of biodiesel content in the fuel blend will increase the density of the fuel. (Moraes M. S. A. 2008) reported that conventional diesel and biodiesel have very similar densities, but it should be considered that the density of biodiesel is affected from the sources of raw material (feedstock) in their productions. From the figure it's obvious that the small amount of diethyl ether diluted in the biodiesel blend fuel is proven to reduce the density of the fuel closed to diesel fuel for B30DE6.

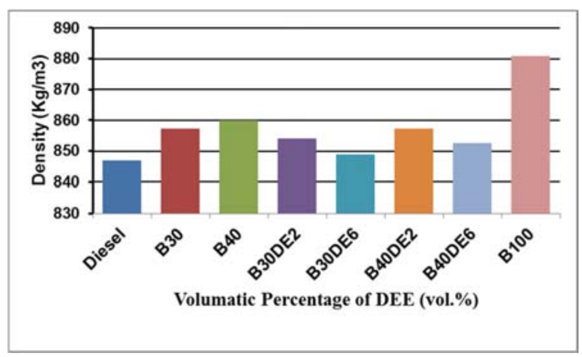

Figure-4. Variation of density.

Acid value analysis

The acid value number is defined as the amount of potassium hydroxide (KOH) in milligrams that is necessary to neutralize free fatty acids (FFAs) contained in 1 gram of oil. It possesses as the vegetable oil quality indicator to monitor the oil degradation during storage period. According to ASTM D 7467, the maximum value of acid number is 0.5 mgKOH/g (Kardash & Tur'yan 2005).

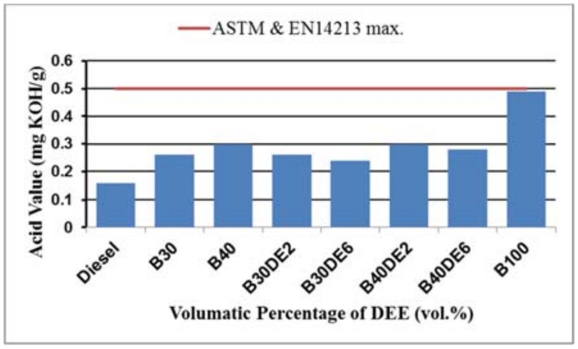

Figure-5. Variation of acid value.

Figure-5 presents the acid value for the tested fuels. It can be seen from the figure that the acid value for B100 is the highest at 0.49 mgKOH/g. On the other hand, the acid value for diesel is the lowest at 0.16 mgKOH/g. However, the acid value for blended biodiesel increase with the blending increase. From the figure it's clear that the acid value slightly affected by adding diethyl ether additive with the mentioned percentage. All the fuel samples meet the ASTM D7467 acid value requirement.

Pour point analysis

The addition of DEE to the blended fuel improved low temperature operability compared to the blended fuel without additive since the freezing points of DEE (-117.4 ^{o}C) are substantially below the temperature at which biodiesel typically undergoes solidification.

Addition of DEE to blended fuel B30 results in a dramatic decline in pour point (PP) as shown in Figure-6. The maximum reduction of PP for the blended fuel with DEE was 23 ^{o}C at 6% DEE addition compare to B100. The low-temperature properties of biodiesels not indicated in ASTM D7467 standard as it related to climatic conditions.

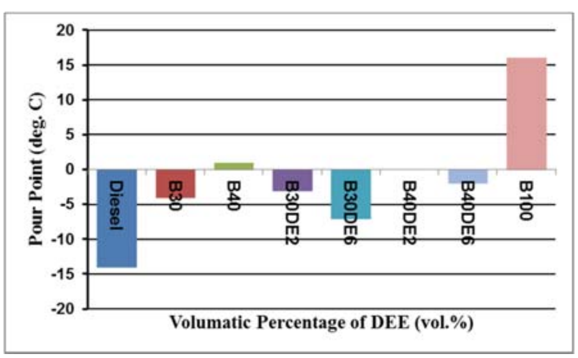

Figure-6. Variation of pour point.

Calorific value analysis

Due to its high oxygen content, biodiesel has lower energy values per unit mass than petroleum diesel. Therefore, increasing the blend level of biodiesel in blended fuel results in decreasing the energy content.

Figure-7 presents the calorific value of the fuels measured by Bomb Calorimeter. It can be seen from the Figure that the calorific value of biodiesel (B100) is lower than that of mineral diesel by 13% and the calorific value of diesel fuel is the higher. From the figure it's found that the small amount of diethyl ether diluted in the biodiesel blended fuel slightly reduce the calorific value compare to that of blended fuel without additive. The calarofic value does not indicate in the ASTM D7467 standard, all fuel samples meet the EN14213 requirement for the calorific value (minimum 35 MJ/kg).

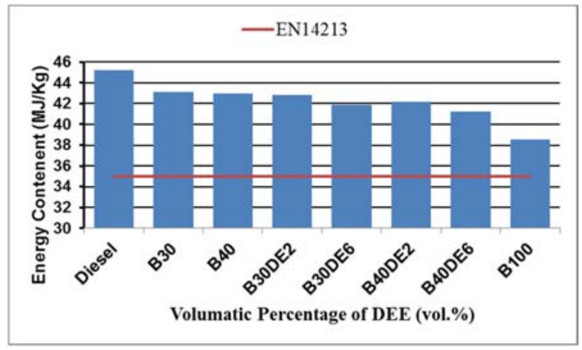

Figure-7. Variation of calorific value.

CONCLUSIONS

The objective of this study was to characterize how the key fuel properties changed when diethyl ether was added to palm oil methyl esters-diesel blended fuel B30 and B40. According to the experimental results:

a) The density and kinematic viscosity of the blended fuel significantly decrease with the increase of additive concentration and the maximum effect shown with 6% DEE additive to the blended fuel B30 where the density reduced closed to that of diesel fuel and the viscosity reduced below that of mineral diesel.
b) The acid value of blended fuel slightly improved with increasing DEE content.
c) Increasing diethyl ether additive with blended fuel resulted in a significant dramatic difference in low temperature performance, with Minimum pour point -7 ^{o}C when adding 6% DEE with blended fuel B30.
d) The heating value of the blended fuel decreases slightly with increasing DEE portion in the blends. Adding 6% DEE to the blended fuel B30 results in about 1% reduction in heating value. The minimum heating value was for B100, which is still satisfying the limits of the EN 14213.
e) Finally, B30DE6 blended fuel exhibited slightly superior low temperature performance, and properties and may and suggested as a suitable fuel for diesel engine.

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