Journal of Energy Technologies and Policy www.iiste.org
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.3, No.11, 2013 – Special Issue for International Conference on Energy, Environment and Sustainable Economy (EESE 2013)

Characterization of Diesel-Hydrogen Peroxide Fuel Blend

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Abstract

In the present work, the outcome of Hydrogen peroxide–diesel fuel blends on the physicochemical properties and kinetic study has been studied. A various blends of diesel-hydrogen peroxide ranging from 5% hydrogen peroxide (H_2O_2), up to 15% by volume in several fuel blends were experimentally investigated and compared with standard diesel fuel. A new emulsifier has been developed for obtaining better emulsion between diesel and hydrogen peroxide. According to ASTM Standard for fuel tests, the results showed that hydrogen peroxide is capable of enhancing the diesel fuel properties. This is due to the presence of additional oxygen atom within the H_2O_2 molecule which can enhance the combustion process and ultimately affecting the exhaust emission.

Keywords:ASTM test, diesel, hydrogen peroxide, physicochemical properties.

1. Introduction

Diesel engines are a type of internal combustion engine. Rudolf Diesel firstly designed the diesel engine to use coal dust and vegetable oil as a fuel. Rudolf subsequently tested it with diesel derived from various type of oils including some vegetable oils, such as peanut oil, to power the engines, which he exhibited at the 1900 Paris Exposition and the 1911 World's Fair in Paris (Mustufa and Havva, 2008). Generally, petroleum-derived diesel comprises of about 75% saturated hydrocarbons (primarily paraffin's including n, iso, and cycloparaffins), with 25% aromatic hydrocarbons (including naphthalenes and alkylbenzenes). The average chemical formula for common diesel fuel is $C_{12}H_{23}$, ranging approximately from $C_{10}H_{20}$ to $C_{15}H_{28}$(Riazi, 2005).

Investigations on various types of fuels had been conducted in recent years for improving the quality and performance of diesel fuel. Especially for the reduction of emitted pollutants; researchers have focused their interest on the area of fuel related techniques such as, the use of alternative fuels, often in fumigated form, or gaseous fuels of renewable nature that are environmentally friendly (Anand et al., 2011; Lujaji et al., 2011; Torres-jimenez et al., 2011; Yasar et al., 2011; Ying et al., 2008) or oxygenated fuels that show the ability to reduce particulate emissions (Ashok and Saravanan 2007; Chen et al. 2008; Karas et al., 1995; Lin and K. Wang, 2004; X Shi et al., 2005; Jianxin Wang et al., 2009).

Significant attention has been given to alternative fuel with superior physiochemical properties for protecting the environment and enhancing the fuel efficiency aspect, particularly the alcohol based fuels. Much attention has been given to ethanol because of its admirable properties (Chen et al., 2009; Guarieiro et al., 2009; Huang et al., 2009; Kwanchareon et al., 2007; Kwanchareon and Luengnaruemitchai, 2007; ,Rakopoulos et al., 2010; Xingcai et al. 2004a; Xing-cai et al., 2004b) . Also methanol (M100) has been looked into as an alternative diesel fuel for used in heavy-duty vehicles (Cenk et al., 2010; Sayin et al., 2009). Denatured ethanol (E95) had also been used in transport buses, that operated in the Midwest and as a replacement for M100 in transport buses during a period of high methanol prices. Blends of methanol and ethanol used in gasoline, with a focus on blends containing 85% alcohol (M85 and E85) (Ajba et al., 2011; Mehta et al., 2012) were evaluated as alternative light-duty vehicle fuels.

To attain substantial reductions in emissions, it is thought that reformulation of diesel fuels properties has played a very important role (De-gang et al., 2005; Tat and Gerpen, 2002). The reformulation of diesel fuels include; lowering the sulfur and/or aromatic content, or potentially the addition of oxygen atoms within the fuel. It has been shown that many oxygenates were effective in reducing particulate emissions from diesel engines (Neeft et al., 1996; Grabowski and McCormick, 1998; Choi and Reitz, 1999; Beatrice et al., 1999). Therefore, much research was focused on screening of oxygenated fuel additives, including alcohols, esters, and ethers. Dimethyl ether (DME) was regarded as one of the promising alternative fuels or oxygen additives for diesel engines, with its advantages of a high cetane number and oxygen content (Arinan and Orman, 2011).

Hydrogen peroxide (H_2O_2) is a pale blue liquid, slightly more viscous than water, which appears colorless in dilute solution. It is a weak acid along with strong oxidizing properties, and a powerful bleaching agent. It is widely used as a disinfectant, antiseptic, oxidizer, and in rocketry as a propellant. The oxidizing capacity of H_2O_2

is so strong that it is considered a highly reactive oxygen species (Ashok and Saravanan, 2008; Voloshin et al., 2007).

In this study, introduction of H_2O_2 as blend for diesel was carried out experimentally. Various compositions of H_2O_2 were tested in order to enhance the properties of diesel, ranging from lean crude diesel and up to the optimum condition. Poly saccride (PS) based emulsifier reduces the surface tension between the diesel and H_2O_2 and stabilizes the blend for longer period. Previously, Ashok and Saravanan worked on performance and emission characteristics of adding H_2O_2 as an additive with the selected ratio of the most common available emulsifies (Span 80) (Abe et al., 2010; Ashok and Saravanan, 2008; Taylor, 2011).

2. Material &Method

For the experimental work, the reference diesel fuel was obtained from PETRONAS fuel station whilst the commercial grade hydrogen peroxide (30%) was obtained from the Chemical Company of Malaysia Berhad (CCM). Analytical grade acetone (99.9%) and the Agarose were purchased from Merck. Prior to performing the experimental measurements of each material and fuel blends, all the mass measurements were performed using an electrical balance (Dhona 200 D, India) which has a precidsion of 0.0001mg. The densities of each liquid (diesel, H_2O_2, and acetone) were measured with a capillary pycnometer. All experiments are repeated three times for consistency and the average reading was used. The emulsifier was prepared shortly prior to the mixing between the reference diesel (R.D) and the H_2O_2 to form the diesel blend fuel. The reaction between the poly saccride and acetone at a ratio of 1:4 (weight/volume) were conducted in a 250 ml sealed Schott bottle with a magnetic stirrer inserted in the solution and then place on a hot plate at temperature 50 ^oC for 12 hours, which was necessary to obtain the desired characteristics. The diesel/H_2O_2 blends were prepared under closed heating system at room temperature and atmospheric inner oxygen pressure. During diesel/H_2O_2 blends preparation, the amount of poly saccride emulsifier was kept at 5 vol. %, and the volume ratios of H_2O_2 to the reference diesel were varied within the range of 0 to 0.15 vol%. Details of experiments which were performed according to ASTM D-975 methods are shown in Table 1.

Table 3: ASTM standard for Diesel fuel Testing

S. No.	Property	ASTM Method
1	Density	ASTM D-1298
2	Viscosity	ASTM D-445
3	Kinematic Viscosity	ASTM D-445
4	Flash Point	ASTM D-93
5	Fire Point	ASTM D-92
6	Refractive Index	ASTM D-1218
7	Surface Tension	ASTM D-971
8	Ph	ASTM D-4539
9	Moisture Contents	ASTM D-2709
10	API Gravity	ASTM D-287

3. Results& Discussion

3.1Influence of H_2O_2 on density of fuel blend

Density is a key fuel property, which directly affects the engine performance characteristics. Many performance characteristics, such as cetane number and heating value, are related to the density of fuel (Wisniak et al., 2007). The density of diesel fuel usually varies between 0.81 and 0.89 g/cm^3. In this study, the densities of prepared fuel blend are laid between these values. Emulsifier has the lowest density value of 0.6123g/cm^3 among the individual component, while hydrogen peroxide having a density of 1.130 g/cm^3 is higher value than the pure diesel fuel. As a result, the experimentally measured values of densities for the fuel blends as presented in Figure 1 showed higher values than the reference diesel. Although the density of hydrogen peroxide is much greater, the energy content is apparently lower both on a mass and volume basis when compared to the reference diesel fuel (Ashok and Saravanan, 2007). Figure 1 shows the density and API gravity for all the fuel blends with different hydrogen peroxide composition. The density of the fuel blends showed increasing value with the increased in hydrogen peroxide composition in the mixture due to higher density of H_2O_2, having a value of 1.130 g/cm^3. However, the density of the fuel blends does not increase much when the hydrogen peroxide exceeded more than 15%.

Due to the reduction in the energy content after the addition of the hydrogen peroxide, more fuel injection into the combustion chamber is required. Nevertheless, such disadvantage is compensated back through the higher cetane number of the fuel blends with the addition of hydrogen peroxide. Higher cetane number of the fuel blends will lead to cleaner combustion hence lowering the emission of carbon monoxide from the engine.

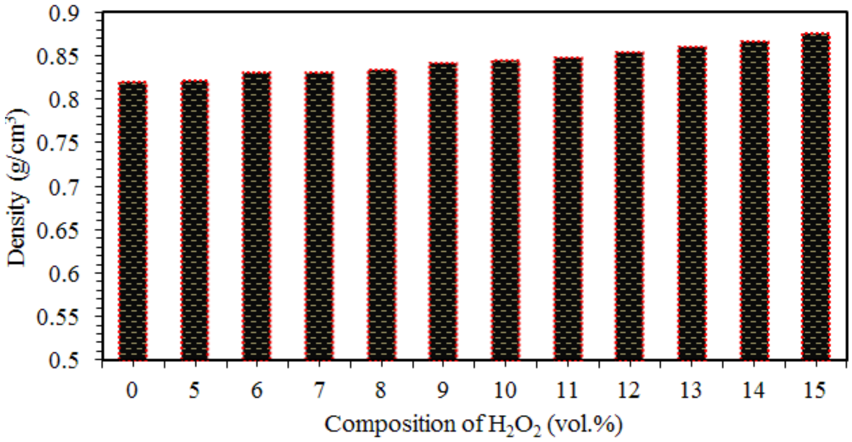

Figure 1: Density (g/cm^3) versus volumetric compositions of H_2O_2

3.2Influence of H_2O_2 on Viscosity of blend fuel

The viscosity of a fluid demonstrate its resistance to shear or flow, and is a measure of the fluids adhesive/cohesive or frictional properties. Usually the viscosity of diesel fuel varies between 1.8 and 4.9 cP (Alptekin and Canakci, 2008). In the study, the viscosities of the prepared diesel fuel blend were found to be well within these values. The value of the viscosity of pure reference diesel fuel is 3.84 cP whilst the viscosity of the emulsifier is 10.5 cP which is the highest among the components. The hydrogen peroxide has a viscosity of 1.245 cP, which is relatively much lower compared to the diesel fuel. The experimental values of the viscosities along with the kinematic viscosities of the fuel blend are presented in Figure 2. Only small changes in the value of the viscosity was observed as the composition of hydrogen peroxide in the diesel fuel blend varied but the changes did not reflect a linear pattern. Viscosities play very important role in fuel atomization and appropriate distribution in the combustion chamber. The viscosity of fuel blends slightly decrease with the increased in the amount of hydrogen peroxide presence in the mixture due to the lower viscosity value of H_2O_2 which is 1.145 cP.

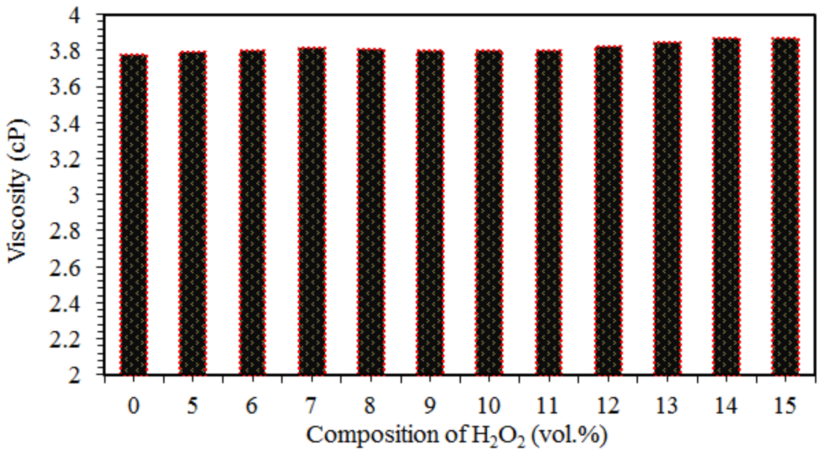

Figure 2: Viscosity versus volumetric compositions of H_2O_2

3.3Influence of H_2O_2 on *pH Content of fuel blend*

The pH of a diesel fuel usually varies between 3.6 to 5.6 . In this study, the pH value of the prepared diesel fuel blend was found to be well within these values. Emulsifier has the highest pH value of 6.4 among the individual component, while hydrogen peroxide having a pH of 3.20, which has a quite lower value than pure diesel fuel. The experimental pH values of the diesel fuel blend as presented in Figure 3 showed that the pH of each blend fuels has lower than those of the reference diesel. Although the pH of hydrogen peroxide is much lower, subsequently the addition of hydrogen peroxide improved the acidic nature of the fuel blend. The pH value of fuel blends decreases with the increased in the amount of hydrogen peroxide in the mixture due to lower pH value of hydrogen peroxide as shown in Figure 3. Again, similar observation was obtained as the pH of the blends exceeded beyond 15% hydrogen peroxide. Below the limit, the changes in the pH of the diesel fuel blends will becomes smaller.

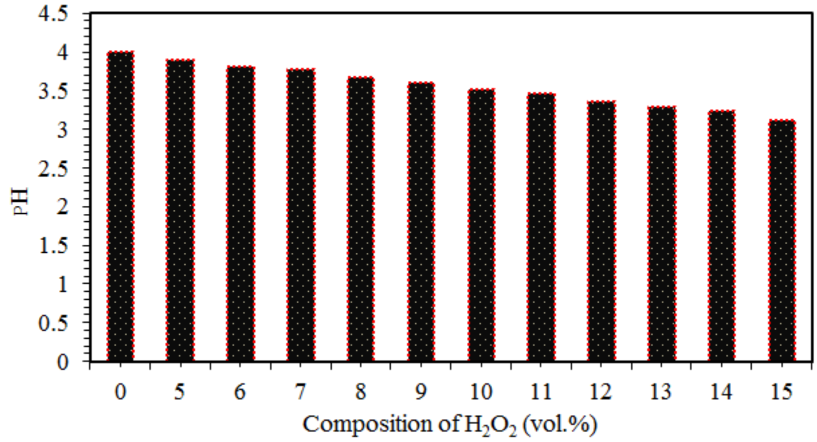

Figure 3: pH versus volumetric compositions of H_2O_2

3.4Influence of H_2O_2 on Refractive Index of blend fuel

Refractive index is a significant property characteristic for fuel characterization, especially for intermediate calculations like hydrogen contents of hydrocarbons and refractivity intercept (Perkash, 2003; Riazi, 2005). Refractive index is independent of units as it is counted as the ratio of the speed of light in air compared to the specific medium. The refractive index value of diesel fuel frequently varies between 1.45 to 1.475. In this study, the refractive index value of the prepared fuel blend is well within the stated values. The order of the refractive index for the three components could be arranged in the sequence of pure diesel fuel, hydrogen peroxide and the emulsifier with the latter having the lowest value. Consequently, the experimental values of the refractive index and the fuel blend compositions are presented in Figure 4. From the figure, it is clearly illustrated that the refractive index of the fuel blends decreases slightly with the increased in the amount of hydrogen peroxide in the fuel blends.

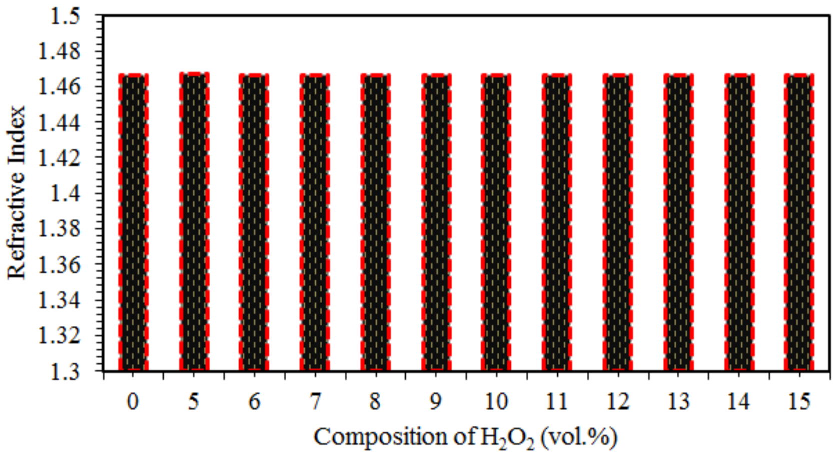

Figure 4: Refractive Index versus volumetric compositions of H_2O_2

4. Conclusion

In this experimental study, the effects of adding hydrogen peroxide (H2O2) on diesel fuel blends have been carried out at various compositions ranging between 0 to 15 vol%.. The results of the physicochemical characterizations according to ASTM D-975 (standard diesel fuel Testing) showed that addition of hydrogen peroxide in a diesel fuel blend will alter its properties comprising of density, viscosity, pH and refractive index. The density of the fuel blend increases slightly with hydrogen peroxide composition due to the higher density of the latter. While the viscosity of the fuel blend decreases slightly due to the lower viscosity value of the hydrogen peroxide. The pH of the diesel fuel blend demonstrates larger effect where it decreases linearly as the amount of hydrogen peroxide is increased in the fuel blend respectively. Finally, the refractive index showed extremely small reduction as the quantity of the hydrogen peroxide is increased in the diesel fuel blend.

Acknowledgements: Authors would like to express their sincere gratitude to staff of Department of Chemical engineering UTP Malaysia, for their selfless help and assistance. University Technology PETRONAS financially supported this project.

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