Characterization Of Key Properties Of Diesel-Biodiesel-Ethanol Fuel Blends

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Abstract— **Among the proposed alternatives for diesel engines, biodiesel and ethanol have received much attention because they are renewable and readily produced from a variety of feedstocks using proven technology. The physical and chemical characteristics of alternate fuels are very important for its application in diesel engine. The properties of blends have great impact on the injection, atomization, ignition, and combustion properties, as well as cold start, output power, fuel consumption, and emission characteristics of engine. The objective of this paper is to characterize the key properties of diesel-biodiesel- ethanol blends. The properties such as density, viscosity, flash point, pour point, specific heat, heating value, and cetane number of diesel-biodiesel- ethanol blends are measured experimentally and the oxygen content of these blends is estimated theoretically. The diesel-biodiesel-ethanol blends containing 5% rice bran biodiesel and 5% ethanol (B5E05), 10% rice bran biodiesel and 10% ethanol (B10E10) and 20% rice bran biodiesel and 10% ethanol (B20E10) have all properties very much close to that of the diesel fuel.**

Index Terms— **Diesel, Ethanol, Rice Bran Biodiesel, fuel Properties.**

I. INTRODUCTION

The energy crisis and environmental pollution are significant concern, a next-generation combustion mode for internal combustion engines that can simultaneously reduce exhaust emissions and substantially improve thermal efficiency has attracted increasing attention [1].

As a renewable and oxygen-containing biofuel, ethanol is a prospective fuel for vehicle, which can be blended with diesel or be injected into cylinder directly. There are many studies on the application of ethanol on diesel engine, which focus on the three aspects: application techniques of ethanol on diesel engine, fuel properties of ethanol-diesel blends, and effects on the combustion and emission characteristics of ethanol-diesel blends [2-4]. Ethanol can be used without many modifications in the diesel engine but it has some limitations of lower miscibility, which may cause phase separation as ethanol is immiscible in diesel over a wide range of temperatures. This instability of blends may also be attributed to the higher affinity of ethanol towards water, which promotes phase separation.

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The phase separation can be prevented in two ways. First is the addition of an emulsifier, which acts by lowering the surface tension of two or more substances and the second is the addition of a co-solvent, which acts by modifying the power of solvency for the pure solvent. [5]. Diesel and ethanol fuels can be efficiently emulsified into a heterogeneous mixture of one micro-particle liquid phase dispersed into another liquid phase by mechanical with suitable emulsifiers. The emulsifier would reduce the interfacial tension force and increase the affinity between the two liquid phases, leading to emulsion stability [6]. A suitable emulsifier for ethanol and diesel fuel is suggested to contain both lipophilic part and hydrophilic part, in order to obtain an emulsion of diesel and alcohol. Such chemical structures can be found in biodiesel. [7].

Biodiesels are used because of their similarity to diesel oil, which allows the use of biodiesel-diesel blends in any proportion. The biodiesel allows the addition of more ethanol-blended fuel, keeps the mixture stable and improves the tolerance of the blend to water, so that it can be stored for a long period. The large Cetane number of the biodiesel offsets the reduction of Cetane number from addition of ethanol to diesel, thus improving the engine ignition. The addition of biodiesel increases the oxygen level in the blend. Also biodiesel have lubricating properties that benefit the engine, and are obtained from renewable energy sources such as vegetable oils and animal fats. Similar to ethanol, biodiesel have a great potential for reducing emissions, especially particulate materials [8].

The above studies reveal that the diesel-ethanol-biodiesel blends can be used as alternative fuels for diesel engines. Recent research has shown that the use of diesel-ethanol-biodiesel blends can substantially reduce emissions of CO, total hydrocarbons (HC), and particulate matters (PM) [9]. The mixing of biodiesel and bioethanol with diesel significantly reduces the emission of particulate matter because the blended biofuel contains more oxygen [10]. Hadi rahimi et al [11] showed that the bioethanol and sunflower methyl ester can improve low temperature flow properties of diesel-ethanol-biodiesel blends due to very low freezing point of bioethanol and low pour point of sunflower methyl ester. The power and torque produced by the engine using diesel-ethanol-biodiesel blends and conventional fuel were found to be very comparable. The CO and HC emission concentration of diesel-ethanol-biodiesel blends decreased compared to the conventional diesel fuel and even diesel–biodiesel blends. Hwanam Kim, Btungchul Choi. [12] investigated the exhaust gas characteristics and particulate size distribution of PM on a CRDI diesel engine using diesel, biodiesel and ethanol blends. They observed the reduced CO, HC, smoke emissions and total number of particles emitted, but increased NOx emissions. Xiaobing Pang et al [13] reported that the use of biodiesel-ethanol- diesel blend could slightly increase the emissions of carbonyls and NOx but significantly reduce the emissions of PM and THC. Prommes Kwanchareon et al; [14] studied solubility of a diesel-biodiesel- ethanol blend, its properties and its emission characteristics from diesel engine. They found that the blended fuel properties were close to the standard diesel except flash point. It was also found that CO and HC emissions reduced significantly at high engine load, whereas NOx emissions increased compared to those of diesel.

The above studies reveal that the diesel-biodiesel-ethanol blends reduce CO, HC, PM, Smoke emissions and increase NOx emissions compared with the diesel fuel.

There is a little research on the use of rice bran oil biodiesel in diesel-biodiesel-ethanol blends for diesel engines. The performance and emission characteristics of the biodiesel blended up to 20% were close to that of diesel fuel [15, 16].

Rice is the main cultivation in subtropical southern Asia, and it is a staple food for a large part of the world's human population especially in east, south and south-east Asia, making it the most consumed cereal grain. Rice Bran Oil (RBO) is extracted from the germ and inner husk (called bran) of the rice. Rice bran is mostly oily inner layer of rice grain which is heated to produce RBO [17]. RBO is not a common source of edible oil compared to other traditional cereal or seed sources such as corn, cotton, sunflower or soybean. . Until recently, rice bran was used mostly as animal feed and the most of the oil production is used for industrial applications. One of the best ways for the potential utilization of RBO is the production of biodiesel [18].

The physical and chemical characteristics of diesel-biodiesel-ethanol blends are very important to its application on diesel engine. The stability, density, viscosity, specific heat, heat value and cetane number of blends have great impact on the injection, atomization, ignition and combustion properties, as well as cold start, output power, fuel consumption and emission characteristics of engine. Additionally, the poking and leakage of conventional tank, fuel pipe, and sealing part can be rendered. More stringent demands are necessary for the mixture, transportation, storage, and usage of fuel because of low flash point of ethanol-diesel blends [19, 20]

In the present investigation the properties of diesel-biodiesel-ethanol blends are investigated and compared with that of the diesel fuel.

II. MATERIALS AND METHODS

The commercial diesel fuel, anhydrous ethanol (99.5% purity) and a biodiesel derived from rice bran oil were used in this test. Diesel-Ethanol-Biodiesel blends were prepared on the volume basis and the objective was to replace the diesel fuel in maximum quantity but keeping the Cetane index within the acceptable limits.

The Bio-diesel is added as a co solvent to improve the solubility of ethanol in the diesel fuel. The blending method consists of first adding ethanol in diesel fuel, mixing it properly and then adding the biodiesel to form the solution.

The fuel blends are mixed into a homogeneous blend with a magnetic stirrer. The final blend is kept in a glass vial with a screw cap for observation. All these blends are kept motionless at room temperature (25^0C) and the long term stability is observed for 7, 15, 30, 60 and 90 days. The ternary diagrams are prepared on the basis of the observations. A homogeneous solution is obtained up to 15% of ethanol and phase separation is observed with 20% of ethanol when 5% rice bran biodiesel is used as a co-solvent in diesel-rice bran biodiesel-ethanol blends. A homogeneous solution is obtained up to 30% of ethanol and phase separation is observed with 35% of ethanol when 10% and 20% rice bran biodiesel is used as a co-solvent in diesel-rice bran biodiesel-ethanol blends. The phase separation is observed at 30%, 20% and 15% of ethanol with 30%, 40% and 50% rice bran biodiesel respectively in the blends. The phase separation is observed at 10% of ethanol with 60%, 70% and 80% of rice bran biodiesel in the blends.

Among the fuel blends studied, those falling in the single phase region are further evaluated to investigate the effect of three-component ratios on the fuel properties. The following fuels are selected from the soluble region for further investigation.

A. Diesel-rice bran biodiesel-ethanol blends (5% rice bran biodiesel as an additive):

1. Diesel fuel(DIESEL)
2. Rice bran biodiesel (RBD100)
3. 95% diesel + 5% rice bran biodiesel (DRBD5)
4. 90% diesel + 5% rice bran biodiesel + 05% ethanol (B5E05)
5. 85% diesel + 5% rice bran biodiesel + 10% ethanol (B5E10)
6. 80% diesel + 5% rice bran biodiesel + 15% ethanol (B5E15)

B. Diesel-rice bran biodiesel-ethanol blends (10% rice bran biodiesel):

7. 90% diesel + 10% rice bran biodiesel (DRBD10)
8. 80% diesel + 10% rice bran biodiesel + 10% ethanol (B10E10)
9. 70% diesel + 10% rice bran biodiesel + 20% ethanol (B10E20)
10. 60% diesel + 10% rice bran biodiesel + 30% ethanol (B10E30)

C. Diesel-rice bran biodiesel-ethanol blends (20% rice bran biodiesel with 10%
increment ethanol):

11. 80% diesel + 20% rice bran biodiesel (DRBD20)
12. 70% diesel + 20% rice bran biodiesel + 10% ethanol (B20E10)
13. 60% diesel + 20% rice bran biodiesel + 20% ethanol (B20E20)
14. 50% diesel + 20% rice bran biodiesel + 30% ethanol (B20E30)

PROPERTIES MEASUREMENT

Density: It is an important property of any fuel which affects the engine performance characteristics. Fuel atomization efficiency and combustion characteristics are influenced by the density [21]. The density of the fuels is measured by using an electronic analytical balance. It is a high accuracy mass measuring device.

Viscosity: Viscosity is another very important fuel property. It affects the fuel drop size, the jet penetration, quality of atomization, spray characteristics and the combustion quality. The operations of the injection systems in the CI engines are also affected by it, especially at lower temperatures, when the fluidity of the fluid is reduced. For every engine there is a highest and a lowest limit for the viscosity of a fuel to be used in that engine [22]. The viscosity of the fuel samples is measured by using Redwood Viscometer No.1.

Flash Point: Flash point and flammability limits of a fuel describe its flammability. Flammability limits can be described as the maximum and minimum concentrations of combustible vapor in the air and the temperatures at which the vapor occurs, that will propagate a flame after sufficient ignition energy is provided. The flash point is the temperature of the lowest value, which is corrected to a barometric pressure of 101.3 kPa at which the vapor overhead the sample is ignited with the application of an ignition source under specified test conditions. It gives an estimation of the temperature at which the vapor pressure reaches the lower flammable limit. It does not affect the combustion directly rather high flash point of fuel makes it safer regarding its handling, transportation and storage [23]. The flash point of biodiesel should be greater than 120^0 C (EN 14214), for fossil diesel, it should be higher than 55^0 C (EN 590) and for the bioethanol it should be below 16^0 C. The flash point of the fuels is measured by using Pensky-Martens apparatus.

Pour point: The pour point is the lowest temperature at which a liquid can flow. As the temperature of a fuel approaches to its pour point it becomes cloudy due to the formation of crystals and finally the crystals solidify. This causes major operability problems [24].

Cetane number: Cetane number (CN) of a CI engine fuel can be defined as the measurement of the combustion quality of a fuel during compression ignition. The cetane number and cetane index is in proportion to the density value . The measurements those determine the overall fuel quality, cetane number (CN) is a significant one among them. [25]. The cetane number of the fuel samples is measured by using K88600 Portable Octane Analyzer with Cetane Index and Cetane number.

Fuel oxygen content: The use of oxygenated fuel improves fuel combustion and reduces the engine emission level. The oxygen content was estimated theoretically.

Calorific value: Heat of combustion or the calorific value of a fuel blend is another very important property to determine its suitability as an alternative to diesel fuel. Lower heating value or the net calorific value of a fuel blend influences the power output of an engine directly. The calorific value of the fuels is measured with the help of a Bomb calorimeter.

III. RESULTS ABD DISCUSSIONS

The properties of the diesel and the blends DRBD5, B5E05, B5E10 and B5E15 are measured and given in the Table 1. It is evident from the table that both density and viscosity increases with the addition of 5% rice bran biodiesel to the diesel fuel. The increasing amount of ethanol reduces both the density and viscosity of D-RBD-E blends. The flash point slightly increases with addition of rice bran biodiesel to the diesel fuel and decreases with the increasing amount of ethanol in D-RBD-E blends. As the flash point of D-RBD-E blends is much lower than that of the diesel fuel care should be taken during storage and transportation of D-RBD-E blends. The cetane number increases with the addition of rice bran biodiesel to the diesel fuel and decreases with the increasing amount of ethanol in the D-RBD-E blends when compared with diesel fuel.

The lower the cetane number, the poorer will be the ignition quality. Cetane number has effects on the engine startup, combustion control and engine performance. Auto ignition temperature and oxygen content of the blends increases with the addition of both rice bran biodiesel and ethanol. The heating value decreases with the increasing amount of ethanol in the blends. The pour point temperature of all the D-RBD-E blends is lower than that of the diesel fuel and decreases with the increasing amount of ethanol in the blends. This finding is evidence for an advantage in D-RBD-E blends utilization.

Table 1. Properties of Diesel, DRBD5, B5E05, B5E10 and B5E15

The physical and chemical properties of the diesel fuel and the

Property parameters	**Diesel fuel**	**DRBD5**	**B5E05**	**B5E10**	**B5E15**
Density at 20 ^{0}C, kg/m3	840	843	842	830.5	829.5
Viscosity at 40^0 C, cSt	3.4	3.48	3.418	3.34	3.213
Flash point, ^{0}C	71	77	27	23	21
Auto-ignition temperature, ^{0}C	225	231	238	246	264
Pour point, ^{0}C	4	1	-1	-2	-3
Cetane number	48	48.2	47.9	47.5	46.8
Oxygen content, wt%	0.4	1.435	2.6625	4.3825	6.1025
Net heating value, MJ/kg	43.5	43.345	42.426	41.591	40.756

blends DRBD10, B10E10, B10E20 and B10E30 are shown in the Table 2.

Table 2. Properties of Diesel, DRBD10, B10E10, B10E20 and B10E30 blends

Property parameters	**Diesel fuel**	**DRBD 10**	**B10E 10**	**B10E 20**	**B10E 30**
Density at 20 ^{0}C, kg/m3	840	845	839	831	825
Viscosity at 40^0 C, cSt	3.4	3.523	3.318	3.248	2.902
Flash point, ^{0}C	71	82	25	22	20
Auto-ignition temperature, ^{0}C	225	237	248	265	287
Pour point, ^{0}C	4	1	-2	-5	-6
Cetane number	48	48.3	47.6	45.8	44.8
Oxygen content, wt%	0.4	1.485	4.925	8.365	11.8
Net heating value, MJ/kg	43.5	43.022	41.352	39.682	38.012

It is observed that the density of D-RBD-E blends decreases with the increasing component of ethanol. A similar effect is also observed for the viscosity of the blends. Both the viscosity and density are within the acceptable limits for standard diesel engines. The pour point of D-RBD-E blends reduces from -2 to -6^0 C making them suitable for cold climate conditions. The flash point of the fuel is the main factor that affects the storage classification of fuels; consequently precautions need to be taken in handling and transporting the fuel. Generally, flash point is dominated by the fuel component in the blends. The flash point of D-RBD-E blends is mainly dominated by the ethanol. The flash point reduces with the increasing amount of ethanol in the blends. The oxygen content increase and heating value decrease with the increasing amounts of rice bran biodiesel and ethanol in D-RBD-E blends. The cetane number slightly increases with the addition of rice bran biodiesel to the diesel fuel and decreases with the increasing amount of ethanol in D-RBD-E blends.

The physical and chemical properties for the diesel fuel and the blends DRBD20, B20E10, B20E20 and B20E30 are shown in the Table 3. The results show that the density of the D-RBD-E blends do not change significantly compared with diesel fuel, as ethanol and biodiesel compensates for each other. The viscosity increases with the addition of rice bran biodiesel to the diesel fuel and decreases with the increasing ethanol component in the D-RBD-E blends. The density and viscosity values of all these blends are acceptable as they are within the standard limit of high speed diesel fuel. The flash point of the blends reduced with the increasing amount of ethanol and is much lower than that of the diesel fuel, in the range of 18 to 22^0 C. These blends are highly flammable with a flash point that is below the atmospheric temperature. Hence care should be taken while handling and transporting these blends.

The pour point of the blends decreases with the increasing amount of ethanol due to low pour point of ethanol. It will allow the blends to use in a better way at low temperatures. The minimum pour point of -5^{0}C is observed with the blend B20E30.

The cetane number of D-RBD-E blends decreases with the higher amount of ethanol. It is due to the lower cetane number of the ethanol. However, biodiesel will improve this property due to its high cetane number. The heating value of D-RBD-E blends decreases with the addition of ethanol and rice bran biodiesel. It may be due to lower heating values of ethanol and rice bran biodiesel. The oxygen content of D-RBD-E blends increases with the addition of rice bran biodiesel and ethanol. However 50% replacement of the diesel with 20% rice bran biodiesel and 30% ethanol increases the oxygen content by 12.89%.

Table 3 Properties of Diesel, DRBD20, B20E10, B20E20and B20E30 blends

Property parameters	Diesel fuel	RBD20	B20E10	B20E20	B20E30
Density at 20 ^{0}C, kg/m3	840	848	840.5	832.5	821
Viscosity at 40^0 C, cSt	3.4	3.646	3.441	3.236	3.014
Flash point, ^{0}C	71	90.5	22	20	18
Auto-ignition temperature, ^{0}C	225	244	255	276	298
Pour point, ^{0}C	4	1	-2	-4	-5
Cetane number	48	48.5	47.8	47.1	46.2
Oxygen content, max wt%	0.4	2.57	6.01	9.45	12.89
Net heating value, MJ/kg	43.5	42.545	40.875	39.143	37.535

CONCLUSIONS

- The density and viscosity of all the diesel-biodiesel blends are slightly higher than the diesel fuel but are in the standard limits. The viscosity and density of diesel-biodiesel-ethanol blends B5E05, B10E10 and B20E10 are almost same as that of diesel fuel.

- The flash point of diesel-biodiesel blends is higher than that of the diesel fuel whereas the all the diesel-biodiesel-ethanol blends have very much lower values. Hence care should be taken while storing and transportation of diesel-biodiesel-ethanol blends.
- The auto-ignition temperature of all the diesel-biodiesel blends and diesel-biodiesel-ethanol blends is higher when compared with diesel fuel.
- The cetane number of diesel-biodiesel blends is slightly higher than that of the diesel fuel where as the cetane number of all the diesel-biodiesel-ethanol blends is lower than that of diesel.
- The oxygen content of all the diesel-biodiesel blends and diesel-biodiesel-ethanol blends is much higher than that of diesel fuel where as the net heating value of all these blend is slightly lower than the diesel fuel.
- The diesel-biodiesel-ethanol blends B5E05, B10E10 and B20E10 have all properties close to that of the diesel fuel.

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