Effects of Diethyl Ether on Fuel Characteristics of Neem Oil Biodiesel

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Abstract - Due to continuous depletion of petroleum based fossil fuels accompanied by tremendous increase in consumption and higher energy demand, it has become necessary to find an alternative fuel for diesel. Biodiesel, a clean renewable fuel, has certainly been considered as the best substitute for diesel. It can replace diesel satisfactorily but some problems related to fuel properties persist. A few being, higher density and viscosity, poor cold flow properties compared with diesel, which affects the performance of biodiesel. To overcome these problems, Diethyl Ether (DEE) an organic compound, is used as a fuel additive with biodiesel for enhancing the fuel properties. In this paper, an experimental investigation has been presented, to evaluate the effects of DEE on fuel characteristics of Neem Oil Ethyl Ester (NOEE) or Neem oil biodiesel. Diethyl Ether has been blended with NOEE in 5%, 10%, 15% by volume. These fuel blends are then tested for their fuel characteristics and results have been compared with those of biodiesel specification - IS 15607: 2005. The final results indicate that by increasing the percentage of DEE in NOEE, there is an improvement in fuel properties viz viscosity, density, flash point, pour point and a slight reduction in calorific value. This reveals that using DEE in small proportion with biodiesel can be a promising fuel.

Keywords - Fuel, Neem Oil, Biodiesel.

1. INTRODUCTION

Energy is an essential input for the technical development and industrialization of any country. Petroleum products are the main energy resources, particularly diesel is the predominant source of energy. In general, diesel is a liquid obtained from fossil fuels and used to run diesel Engine. Today, diesel engine is used as prime mover in various fields such as transport, agriculture and in many heavy duty applications. The massive use of diesel fuel with growing energy demand and the depletion of fossil fuel resources encourage the world to find an alternative fuel for diesel which can be produced from the resources locally with in the country. So, use of vegetable oil based biodiesel as an alternative fuel for diesel is promoted. The biodiesel is produced from the edible oil or non-edible oil by esterification process. Esterification is a chemical reaction between triglyceride molecules present in the vegetable oils and alcohol in the presence of a catalyst to produce mono-esters (biodiesel) and glycerol. Triglyceride is the main constituent of vegetable oil and formed from one molecule of glycerol, combined with three molecule of fatty acid. The glycerol molecule has 3 hydroxyl (OH-) groups and each fatty acid has a carboxyl group (COOH-). In triglyceride, hydroxyl group of the glycerol joins the carboxyl group of the fatty acid. So fatty acids are actually derived from triglyceride. When fatty acids are not attached to any other molecule, they are known as free fatty acid (FFA).

In present investigation Neem Oil Ethyl Ester (NOEE) is taken as a biodiesel. The reason of choosing NOEE as biodiesel is that, it is obtained from neem oil. Neem oil is non-edible oil. Neem tree is an evergreen tree, easily found throughout India. It is accustomed to all kinds of climate and soil. Neem oil is derived by crushing the neem seeds and using mechanical expellers. India has shortage of edible oil, so our biodiesel program is based on non-edible oils like Jatropha, Mahua and Neem oil.

There are several distinct mileages of biodiesel which make it an appropriate fuel for diesel engine. Biodiesel has higher combustion efficiency, cetane number than diesel fuel. It is biodegradable and more than 90% of biodiesel can be biodegraded within 21 days. Biodiesel has lower sulfur and aromatic content so it does not emit toxic gases.

Although biodiesel has many advantages over diesel fuel but it has also some drawbacks such as higher viscosity, higher density and pour point, and lower volatility compared with diesel. In CI engine higher viscosity of biodiesel affects the handling of the fuel in pump and injector system. Due to higher viscosity, poor fuel atomization takes place during the Spraying of fuel and fuel jet tends to be a solid stream instead of small droplets hence the fuel does not get mix with the air required for burning. Larger droplets have poor combustion leading to loss of engine power and fuel economy. Fuel injection system measures fuel by volume and thus engine output power is influenced by change in density due to different injected fuel masses. The low volatility of biodiesel affects the engine starting, length of warm up period, fuel distribution and engine performance. Biodiesel have higher pour point. So the poor cold flow property of biodiesel is also a barrier to their use during cold weather in CI engine. These problems can be overcome by adding some fuel additive with the biodiesel in small proportion. The lower percentage addition of Diethyl ether (DEE) might be expected to improve the cold flow properties of biodiesel and reduce the problems related to viscosity and density. DEE is an organic compound from ether class. It is a colorless highly volatile flammable liquid with odor characteristic. DEE has several favorable properties including exceptional cetane number, high oxygen content, lower viscosity and density and higher volatility which make it an appropriate fuel for CI engine. So here in present work DEE is used as a fuel additive with neem oil biodiesel (NOEE).

Table 1: Physical properties of biodiesel from different oil sources and their comparison with diesel and DEE.

Properties	DEE	Diesel	Peanut oil	Soya bean oil	Palm oil	Sunflower oil	Mahua oil	Jatropha oil
Kinematic viscosity (cSt)	0.23	2.71	4.9	4.5	5.7	4.6	6.2	4.78
Density (gm/cc)	0.713	0.837	0.883	0.885	0.88	0.86	0.865	0.8636
Calorific value (MJ/kg)	36.84	42.5	33.6	33.5	33.5	33.5	41.6	40-42
Cetane number	125	45-55	54	45	62	49	47	61-63

2. EXPERIMENTAL PROCEDURE:

Researchers have found that above 2.5% FFA level in the vegetable oils, it becomes very difficult to produce biodiesel in single step esterification process. So, neem oil which contains 20 % FFA by weight requires multiple chemical steps to produce biodiesel from this. In present work two step esterification processes has been used to obtain the neem oil biodiesel from the neem oil. Esterification followed by transesterification. In esterification process, triglycerides which present in oil reacted with ethanol (Alcohol) as a reagent in presence of acid catalyst (sulfuric acid), so FFA content in oil reduced up to the considerable amount. In transesterification process, reduced fatty acid oil again reacted with alcohol in presence of alkali catalyst (KOH).

After completion of transesterification reaction two main products exist: ester and glycerol. This ester is used as a biodiesel. Then neem oil biodiesel mixed with DEE in 5%, 10% and 15% by volume and conducted for fuel properties test.

3. PREVIOUS WORK

Several experimental investigations have been carried out by researchers to evaluate the engine performance using DEE as a supplement or fuel additive in case of neat diesel. Subramanian & Ramesh (2008) carried out performance experiments on a single-cylinder, air-cooled, DI diesel engine fueled with diesel fuel, blended with 5%, 10% and 15% (by weight) of DEE. The optimum blend of diethyl ether was found as 10% based on brake thermal efficiency. Mohanan (2003) carried out performance and emissions experiments on a Kirloskar AV1, single-cylinder, DI diesel engine fueled with diesel fuel, blended with 5%, 10%, 15%, 20% and 25% (by vol.) of DEE. The most favorable blend was 5%, resulting in low smoke and CO emission levels as well as high brake thermal efficiency against the neat diesel fuel case. On the contrary, for the higher blends and especially the 20% and 25% this picture was inverted, showing increased smoke and CO emission levels as well as deteriorated brake thermal efficiency against the neat diesel fuel case. For the higher blends, non-uniformity of the engine operation and heavy smoke were observed. This was possibly attributed to the phase separation of blends that resulted from cavitation in the injector nozzle, thus eventually leading to poor fuel injection (large droplets) in the combustion chamber. Iranmanesh (2008) carried out performance and emissions experiments on a Kirloskar TAF1, single-cylinder, air-cooled, DI diesel engine fueled either with diesel or bio-diesel fuel, blended with 5%, 10%, 15% and 20% (by vol.) of DEE. The 5% DEE/diesel fuel blend and the 15% DEE/bio-diesel blend were found to be the optimum one in terms of exhaust emissions and performance behavior. In blending of DEE with other fuels, higher than 15% (by vol.), authors reported some problem in miscibility, instability, fluctuation of engine speed and low power output.

From the above description, it is obvious that, there exists a gap concerning the impression of DEE on the properties of fuel, when it is used as a fuel additive with biodiesel. On the basis of property results it can be justified the suitability of fuel for running in CI engine.

4. PROPOSED METHODOLOGY

4.1 Preparation of Neem Oil Biodiesel (NOEE)

In making of biodiesel, for esterification process, 8:1 molar ratio of ethanol to oil and amount of acid catalyst 4.5% weight of oil is used. High fatty acid neem oil reacts with ethanol in the presence of acid catalyst H_2SO_4. The ethanol and sulfuric acid are premixed in round bottom flask and then added the neem oil into the solution. The mixture is then stirred and heated for 1.5 hours at 45°C. After the reaction is over, the mixture is poured into a separating funnel for gravity separation. In 24 hours, impurities settle down in lower layer while the upper layer contains reduced fatty acid neem oil. The lower layer is removed and reduced FFA neem oil is further used for trans-esterification reaction (for conversion into biodiesel).

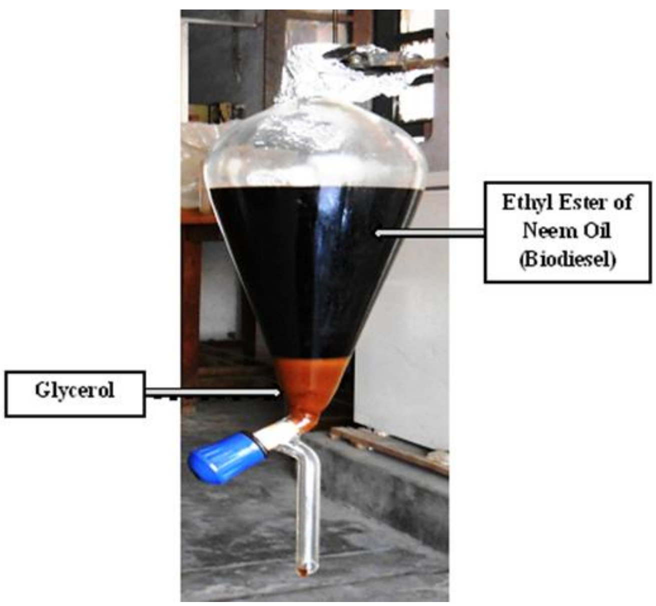

Figure 1: Separation of Ester and Glycerole

FFA of neem oil reduces from 20% to 3% in first step esterification. In the next step of transesterification, reduced FFA neem oil is again reacted with ethanol in presence of a catalyst KOH. For this, 8:1 molar ratio of ethanol to oil with 1% (w/w oil) KOH are mixed with reduced FFA neem oil. The reactants are stirred and heated in round bottom flask for 90 min at 60°C. After the completion of the transesterification reaction, the products are again kept in a separating funnel for gravity separation. In 24 hours, separation takes place in the form of glycerol and Ethyl Ester. The high density glycerol settles down and Ethyl Ester rises to the top. This Ethyl Ester is separated and washed with warm water two to three times. Then final product is heated for 15 min at 70°C and then used as a biodiesel. After ready of neem oil biodiesel (denoted by B100), DEE added into it with low stirring speed at room temperature for 15 min. So that mixture comes to the equilibrium before subjecting it to any property test. In this work, 5%, 10% and 15% DEE (by volume) are added into biodiesel and their names designated as BD5, BD10 and BD15 respective.

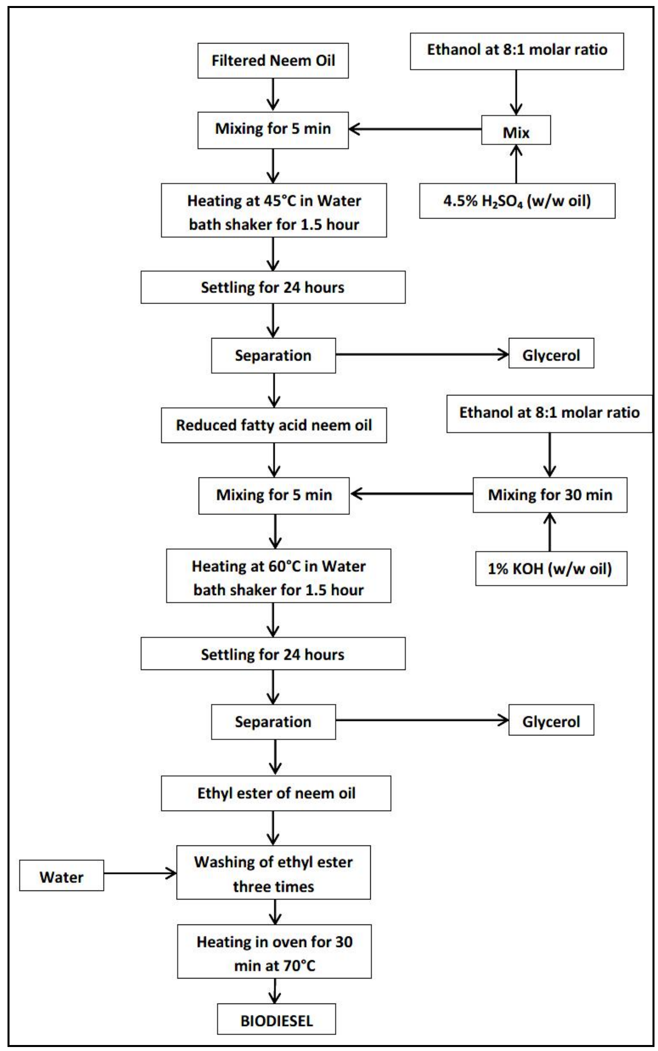

Figure 2: Flow chart of production process of Neem Oil Biodiesel

4.2 Determination of Fuel Properties

All the fuel property tests were conducted in the Bio-Energy Technology Lab, Department of Farm Machinery and Power

Engineering G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The fuel properties viz kinematic viscosity, density, calorific value, cloud point and pour point were determined. The density of selected fuel at 15°C, has been determined as per IS: 1448 [P: 32]: 1992. The Kinematic viscosity of fuels was determined by Red Wood Viscometer No.1 at 38°C in accordance with IP 70/62 issued by Institute of Petroleum, London. With the help of an Isothermal Bomb Calorimeter as per IS: 1448 [P:6]: 1984, the gross calorific value of fuel was determined. The heat of combustion or calorific value of a fuel is an important property since it is the heat produced by the fuel within the engine that enables the engine to do the useful work. Calorific value of a fuel is the thermal energy released per unit quantity of the fuel is burned completely and the products of combustion are cooled back to the initial temperature of the combustible mixture. When the products of combustion are cooled to 25°C practically all the water vapor resulting from the combustion process is condensed. The heating value so obtained is called the higher calorific value or gross calorific value of the fuel. Flash point and fire point were determined with the help of Pensky Marten Apparatus as per IS: 1448 [P-21]: 1992.

As per IS: 1448 [P:10]: 1970 the cloud and pour point of fuel were determined. The cloud point is the temperature at which any solid material, usually paraffin waxes and similar compounds in case of petroleum liquid begin to separate when the sample is cooled under carefully controlled conditions. The pour point is the lowest temperature at which no motion of the fuel sample is observed for 5 seconds on tilting the tube to horizontal position.

Table 2: Properties of Diesel, Neem Oil Ethyl Ester, DEE and fuel blends

Sl. No.	Fuel Blend	Kinematic Viscosity (cSt)	Density (gm/ml)	Calorific value (MJ/kg)	Flash Point (°C)	Fire point (°C)	Cloud point (°C)	Pour point (°C)
1	Diesel	2.6	0.837	43.8	54	59	-12	-16
2	B100	6.29	0.889	39.12	140	147	16	10
3	DEE	0.23	0.713	33.89	-40	-	-	-
4	BD5	5.73	0.878	38.49	102	106	-	8
5	BD10	5.19	0.867	38.33	89	93	-	6
6	BD15	4.65	0.854	38.15	76	79	-	3
7	IS 15607:2005	2.5 to 6	860-890	-	120	-	-	-

5. Experimental Results

The measured fuel properties of all the fuels including diesel, NOEE, DEE, BD5, BD10, and BD15 are summarized in Table 2. There are various fuel quality testing methods and standards to specify the properties of the fuel. Biodiesel specification - IS 15607: 2005 standardizes the properties of biodiesel, which compile the requirement of biodiesel from ASTM D6751-02 testing standard in USA and EN 14214-03 testing standard in Europe.

5.1 Kinematic Viscosity

Kinematic viscosity represents the flowing characteristics of the fuel. It can be seen from the Table 2 that viscosity of fuel blends BD5, BD10 and BD15 are within IS specification limits (up to 6 cSt at 38°C) whereas B100 having kinematic viscosity 6.29 cSt is marginally out of specifications (6 cSt).

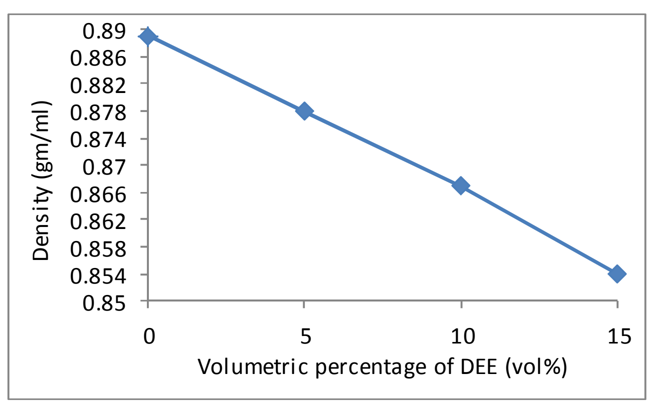

Figure 3: Variation of viscosity with the increasing percentage of DEE

Addition of DEE in biodiesel decreases the viscosity and brings it under the IS specifications. As observed from the Figure.3, the decrement in the viscosity is linear and the viscosity of blends decreases as the DEE proportion increases in the fuel mixture and it varies in the range of 5.73 cSt, 5.19 cSt and 4.65 cSt for BD5, BD10, and BD15 respectively.

5.2 Density

The density of biodiesel is found to be 0.889 gm/ml, which is 4.5% higher than the density of mineral diesel and fulfills the criteria of IS specifications for biodiesel. The densities of NOEE-DEE also show good results and come under the IS specification. Figure.4 represents the variation in density of biodiesel with the increases volumetric percentage of DEE. The density of NOEE-DEE blends decreases linearly. Similar to the kinematic viscosity, density of fuel blends decreases as volumetric percentage of DEE increases in the biodiesel, but these are still above the density of mineral diesel.

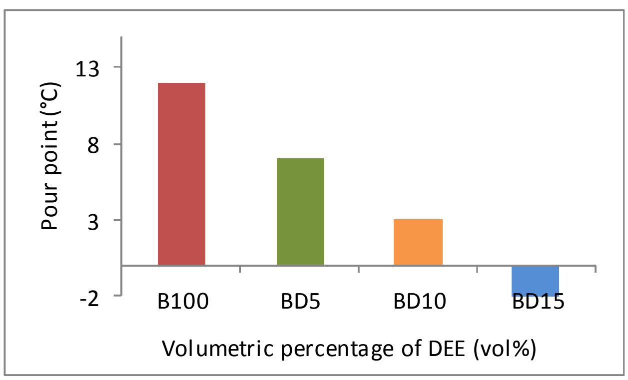

Figure 4: Variation of Density with the increasing percentage of DEE

5.3 Calorific Value

Calorific value or the heat of combustion is the amount of heat energy released during the combustion of a unit mass of fuel. For better fuel characteristics higher calorific value is always desirable. The heating value is not specified in biodiesel specification - IS 15607: 2005 but is prescribed in EN 14213 with a minimum of 35 MJ/kg. Figure.5 shows the calorific value of the NOEE-DEE blends decreasing slightly with the increase in percentage of DEE. This phenomenon sets the limit that DEE can't be used in higher percentage as with other fuels. The minimum heating value of 38.15 MJ/kg was found for fuel BD15. The calorific value of the NOEE-DEE blends satisfies the requirement of EN 14104 standard for all the ranges of blends.

5.4 Flash Point

Flash point is the indication of volatility of the fuel. Lower will be the flash point, higher will be the volatility of the fuel. Flash point indicates the possible presence of highly volatile and flammable material in relatively non-volatile material. The flash point of NOEE is found to be 140°C higher than the IS biodiesel specifications. Addition of DEE causes reduction in the flash point. Figure.5 shows the decrement in flash point of biodiesel with the addition of DEE. The fuel blends BD5, BD10 and BD15 have their flash points 102°C, 89°C and 76°C respectively, and satisfy the requirements of IS- biodiesel specifications.

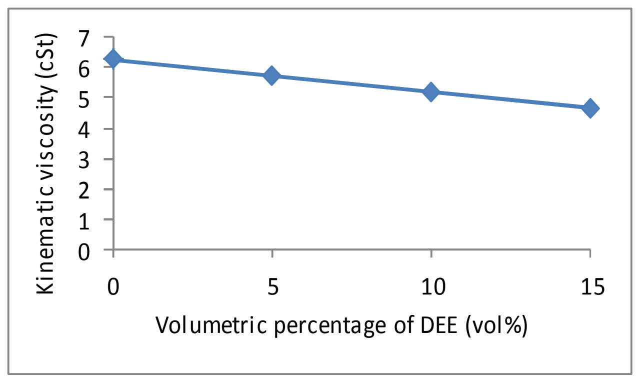

Figure 5: Variation of Calorific Value with the increasing percentage of DEE

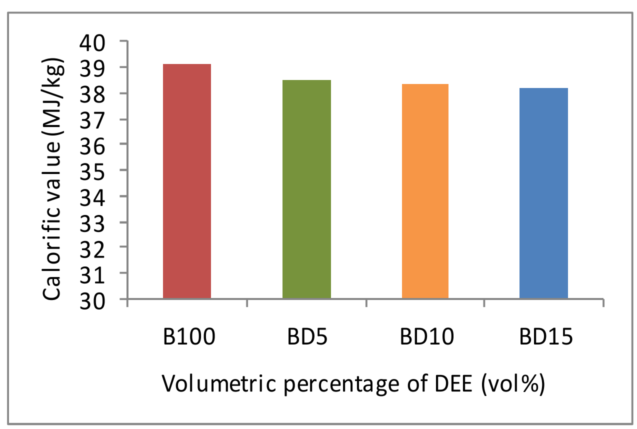

Figure 6: Variation of Flash Point with the increasing percentage of DEE

5.5 Pour point

At ordinary temperature, biodiesel does not have much problem as of either viscosity or solidification but as the temperature falls, there could be a problem of undesirably high viscosity. The next would be the temperature at which a haze or wax or cloud separates and the last would be the lowest temperature (pour point) at which the oil would flow under specified conditions. DEE improves the low temperature operability when it is blended with NOEE. Since the freezing point of DEE (-117.4 °C) is substantially below the temperature at which biodiesel typically undergoes solidification. Addition of DEE to NOEE does not affect the CP, while increasing DEE content from 0 to 15% results in a considerable decline in PP. Figure.6 shows the variations of PP for NOEE with the increase in volumetric percentage of DEE. The maximum reduction of PP for NOEE has been 14°C on adding 15% DEE. The low-temperature properties of biodiesel are not indicated in IS standard, as it relates more to the climatic conditions.

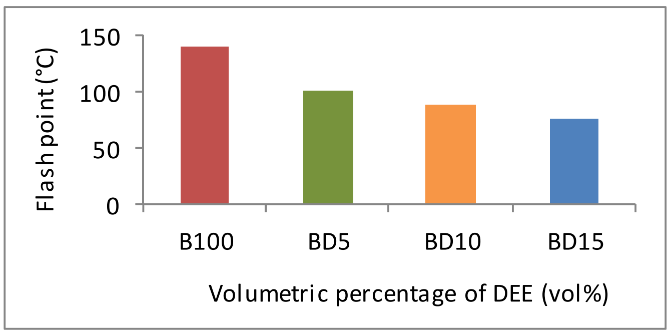

Figure 7: Variation of Pour Point with the increasing percentage of DEE

6. Conclusions

The objective of this study had been to evaluate the effects of DEE on fuel properties, while blending it with Neem Oil Ethyl Ester (NOEE). The kinematic viscosity of tested biodiesel NOEE is 6.29 cSt. The blends obtained by varying the amount of DEE with NOEE show improvement in viscosity. The best value of viscosity for the BD15 comes out to be 4.65 cSt. With increase in DEE content in biodiesel the kinematic viscosity decreases for all blends. Similarly, the density of all fuel blends decreases with increase in DEE proportion. The best value of density is obtained as 0.854 gm/ml for BD15, which is close to the density of mineral diesel 0.837 gm/ml. The calorific value of tested fuel blends reduces with increase of DEE content in biodiesel. In view of improvement of other properties, slight reduction in calorific value is admissible. Although, minimum calorific value 38.15 MJ/kg is obtained for BD15, which is above the minimum value 35 MJ/kg according to the EN 14213 standards. The addition of DEE causes reduction in flash point and fire point of tested fuel. The neat biodiesel shows flash point and fire point as 140°C and 147°C respectively. The addition of 15% DEE brings this value down up to the 76°C and 79°C respectively. This is important to mention that DEE content alters the flash point and fire point to a large extent. Increasing the DEE content in NOEE resulted in a significant difference in low temperature performance, accompanying maximum decrease in pour point by 14°C at 15% DEE compared to NOEE. On the other hand, there has been no significant difference in the cloud point of the biodiesel with DEE. So, DEE used as fuel additive with neem oil biodiesel, improves the viscosity, density, reduces the flash point and fire point and improves the low temperature performance. Hence addition of DEE (by vol.) up to 15% into neat biodiesel can be a promising technique for using biodiesel efficiently.

7. Future Scope

In present investigation DEE in various proportion, added into NOEE (Neem Oil Biodiesel) These fuel blends are then tested for their fuel characteristics. Results of some fuel blends of DEE and Biodiesel found comparable with the Diesel. But there is also scope for the further studies and investigation on some parameters, which are as listing below:

- Performance testing in CI engine, when engine running on various fuel blends of DEE & Neem Oil Biodiesel.
- Exhaust Emission testing, when DEE – Neem Oil Biodiesel blends used as a fuel in Diesel Engine.
- Instead of Neem Oil it can be used some other vegetable oil for making of Biodiesel and blended those with DEE in various proportion and further tested for their fuel characteristics, performance and emission testing in CI Engine. For example: Mahua oil, Jatropha oil.
- It can be Use some other fuel additive instead of DEE to enhance the fuel characteristics of biodiesel.

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