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Experimental Out Comes Related to Property Analysis of Tripartition Fuel Blend – A Step towards New Generation Fuel

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Abstract

The economy of India will be at risk as the finite supplies of petroleum imported from volatile parts of the globe will lead to an eventual depletion. More over for improvement of the ambient air quality, vehicular emissions control technologies with lesser fuel consumption is utmost needed. Vehicular pollution causes severe public health and environmental issues. Generally, major pollutants released by engines are CO, NOx, un-burnt hydrocarbons, smoke and particulate matter. Therefore, the improvement in fuel and diesel engine technologies used in transportation sector have to meet out two major challenges i.e. betterment of engine efficiency and minimization of exhaust emission. For modified fuel identification a detail observation like production process, its properties and exhaust emissions need to be analyzed.

Bio-diesel is considered as oxygenated fuel with good burning efficiency, biodegradable, non-toxic, eco friendly, and better lubrication properties and free from sulphur. In Bio-diesel fuelled engines, sufficient reduction in hydrocarbon (HC), carbon mono-oxide (CO) and particulate matter (PM) emissions is being observed, but NOx emissions observed at higher side. Slightly lower the brake specific fuel consumption (bsfc) and the brake thermal efficiency (BTE) are observed for bio-diesel fuelled engines compare to diesel engines.

Research indicated sensitivity of mahuva biodiesel towards ignition delay. As per study at US department of energy, biodiesel can reduce CO2 emission by 75% and does not contain toxic chemicals like sulphur; acid rain can also be eliminated.

To address above issues controlling low environmental impacts to observe property analysis of tripartition of fuel using direct injection testing in compression ignition engines.

Keywords: *Vehicular emissions, pollutants, emission control, air pollution, alternative fuels, tripartition approach.*

1. Introduction

India has abundant renewable energy sources (Sunlight, wind power, hydroelectric power, bio energy), but hydrocarbon reserves are small. Because of limited country fossil fuel reserves, India hopes for imports of fossil fuels to fulfil energy demand. India's crude oil import bill, including crude oil and petroleum product shipments, raised 9 percent last year to $ 80.3 billion as a result of the seven percent increase percent of the volumes and three percent of the average price of crude oil as per data published by the Ministry of Petroleum.

Gross imports increased by more than five percent to 213 million tonnes (MT) and the gross import bill increased by more than nine percent to $ 70 billion in the last fiscal year compared to $ 64 billion recorded in 2015-2016. Therefore, we have an ambitious plan to develop renewable energy industry. Energy is considered as lifeline of developed society and plays crucial role in economic and industrial growth phase.

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The crude oil import bill of India rapidly increased by 42.23% (Rs. 881,282 Crore) in the last financial year (2018-2019). Overall import to India increased by 1.44% mainly due to purchase of oil while significant fall have been seen in coal, coke, organic and inorganic chemicals import etc. Summary of India crude oil import bill since 2006 to 2019 is depicted in the table 1.1.

Table 1.1 Crude oil import details

Financial year	Import of crude oil (Million Tonne)	Bill of crude oil import (Rs. Crore)
2005-06	99.40	1,71,702
2006-07	111.50	2,19,029
2007-08	121.67	2,72,699
2008-09	132.77	3,48,304
2009-10	159.25	3,75,277
2010-11	163.59	4,55,276
2011-12	171.72	6,72,220
2012-13	184.79	7,84,652
2013-14	189.23	8,64,875
2014-15	189.43	6,87,416
2015-16	202.85	4,16,579
2016-17	213.93	4,70,251
2017-18	220.04	5,66,450
2018-19	228.6	8,81,282

There is a need of energy for socio-economic growth. The excessive consumption of fossil fuels results higher concentration of greenhouse gases as well as disturbance in economy. Any development / research about environmental

friendly energy sources can be considered as an effort to pay much-needed respect to the environment.

2. Vehicle Population Scenario in India

Improved transport sector is prime most necessity for the economic development of any country. India is likely to become the most populous country in the world by 2031, overtaking China's population as per U.N report. The urban population is likely to reach 40% from 30% presently. India's per capita income has risen to Rs 1,12,835 in 2017-18 (upto more than 200 % in last 10 years) and has reached a tipping point in personal ambitions of western life style, and ownership of personal transport. The explosive growth of two wheelers and cars will lead to a massive demand for road infrastructure, urban planning and availability of fuel. Tremendous growth in total population is observed in table 2.1.

Table 2.1 Vehicle population detail

Year	Total Vehicles Population	Percentage Two Wheeler	Percentage Four Wheeler	Percentage Buses	Percentage Goods Vehicles	Percentage Other Vehicles
1951	0.3 million	8.8%	52%	11.1%	26.8%	1.3%
1981	5.4 million	48.6%	21.5%	3%	10.3%	16.6%
2001	55 million	70.1%	12.8%	1.2%	5.4%	10.5%
2015	210 million	73.5%	13.6%	1%	4.4%	7.5%
2018	256 million	84%	14.28%	0.9%	4.2%	7.12%

Because of rapid growth in environmental pollution and excessive increase of fuel rates, meeting energy needs, fulfilment of emission norms create importance of technically and economically feasible alternate fuels which must be eco-friendly and easily available as well.

During starting phase of CI engine vegetable oil was used by researchers and faced many problems like partial combustion, resulting which carbon deposits due to approximately 11 to 17 times more viscous vegetable oil than diesel fuel and lower volatility of oil as well. Because of high end viscosity and less volatility of vegetable oil lessen the suitability as engine fuel and create urgency towards chemically mixing or transesterification to get alkyl esters form.

3. Health Prospects from Vehicle Pollution

Health problems linked with the pollutants include aggravation of respiratory, premature mortality and cardiovascular disease and several other respiratory-related ailments. Carbon monoxide (CO) is a Colourless, odourless and poisonous gas caused by incomplete combustion of fuel enters the blood and binds to haemoglobin, reducing the transport of oxygen even low levels can affect mental function and visual acuity persons in ill health can be more severely affected.

Hydrocarbons (HC) emission in atmosphere is from combustion processes and gasoline vapours with NOx and sunlight, react to form ozone (smog), HC irritates the eyes, destroys building materials and causes crop damage.

Nitrogen oxides (NO_x) results from high temperature combustion nitric oxide is the prominent one, it is the yellow-brown colour in the smog plays a major role in atmospheric reactions caused acid rain and also affects the respiratory system, causing bronchitis, pneumonia and lung infections.

Particulate matter (PM) is general term for airborne particles, some visible (smoke and dust), some not visible, diesel vehicles are the major source can irritate the respiratory system and may also carry metals, sulphates, nitrates etc.

Aldehydes are formed due to partial oxidation of fuel formaldehyde forms 70% and 30% are acetaldehyde of total aldehydes in the exhaust powerful eye and respiratory system irritants.

4. Bio-fuels an Alternative

To upliftment of society cleaner air quality is needed hence technically feasible bio-fuels can be solution towards atmosphere safeguard and control over exponentially escalated crude oil price internationally. Other factor that spurred research interest in alternative and renewable energy sources is the major air pollutant emissions from the motor vehicles in most urban areas. The increased driving distances, increasing size of urban areas and increasing vehicle populations have led to serious pollution problems in many cities.

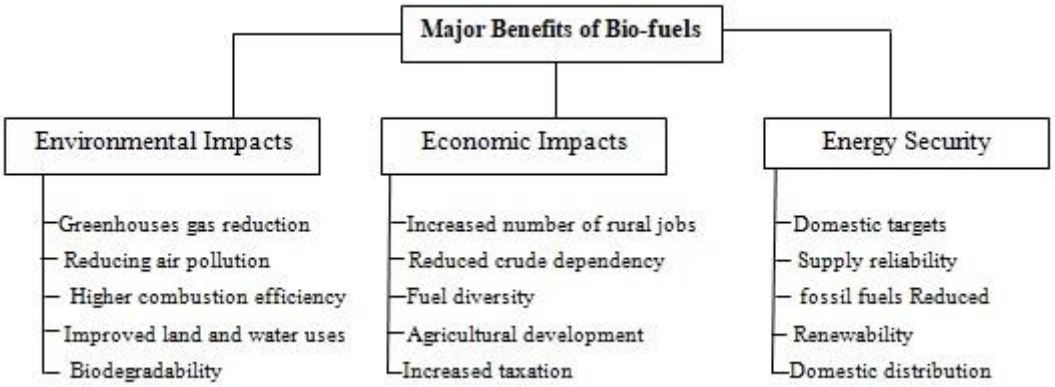

Fig. 4.1 Major Benefits of Bio-fuels

4.1 Stability of Biodiesel and its Effect on Engines

One of the main criteria for quality of biodiesel is storage stability. Degree of un-

saturation makes vegetable oil derivatives susceptible to thermal and/or oxidative polymerization, which may lead to formation of insoluble products causing problems within fuel system. Feed- stocks with larger proportion of saturated fatty acids are more stable than those having larger proportion of unsaturated fatty acids. However, higher portion of saturated fatty acids lowers cloud and pour points. Hence, a major drawback of biodiesel lies in its trade-off between level of saturation of biodiesel and its cold flow properties. Rate of degradation for B20 biodiesel is twice as fast as 100% petroleum based diesel fuel. Further, degradation is accelerated by presence of oxygen, water, heat, and impurities. Degradation of biodiesel may form corrosive products like acids, which may affect negatively fuel injection equipment, and form insoluble gums and sediments that can plug fuel filters. Reaction rate in auto-oxidation schemes is dependent on hydrocarbon structure, heteroatom concentration, heteroatom speciation, oxygen concentration and temperature. Fuel instability problems can be short-term oxidative in stability and long-term storage instability.

5. Mahuva Oil as a Bio diesel

Mahuva oil is converted into mahuva methyl ester by chemical process where mahuva oil molecules (triglycerides) are mixed with methanol molecules using caustic soda as catalyst, which is soluble in methanol to form sodium methoxide then mixed with mahuva oil. Methanol is used because of its cost effectiveness and better technical efficiency.

5.1 Properties of Mahuva oil

The mahuva is a non edible oil tree abundantly found in central India. The kernel of mahuva fruit contains 35–40% of oil which can be a good source of biodiesel. Variations have been observed in physical and chemical properties of mahuva oil because of fruit quality and contents of fatty acids in the fruit. Mahuva bio diesel has been prepared by transesterification process using mahuva oil keeping in view like less mixing of oil, less acid value, less value of water, ash and phosphorous and higher oxidation stability. Finally property analysis of bio diesel is to be compared with standards like ASTM and IS.

Mahuva seed contains around 41.2% saturated and 58.8% unsaturated fatty acid. Viscosity of mahuva oil is significantly decreases using tranesterification process but finally it is more than plain diesel. Other properties like cloud point, pour point are also on higher side than plain diesel.

Table 5.1 Characteristics of diesel & mahuva oil.

Properties	Diesel	Oil of mahuva seeds
Density kg/l (15/40 °C)	0.84-0.85	0.91-0.92
Cold solidifying point (°C)	-14.0	2.0
Flash point (°C)	80	110-240
Cetane number	47.8	51.0
Sulphur (%)	1-1.2	0.13

As diesel fuel has better auto ignition qualities. As biodiesel generally contains about 10 wt% of oxygen; it can be considered as an oxygenated fuel. High oxygen content results in improvement of its burning efficiency and reduction in particulate matter (PM), CO and other gaseous pollutants. However, it also leads to higher production of NO_x (10%) as compared to fossil diesel, particularly under a high-temperature burning environment.

Various researches indicated that for compression ignition (CI) engine, blend of biodiesels and ethanol alone cannot be used as an effective alternative fuels; even diesel-biodiesel blends or diesel-ethanol blends will not fulfil the current requirements of CI engines. Hence an idea is being generated for tripartition blend fuel which is the mixture of diesel, biodiesel and ethanol with optimum proportion.

There is a little research on the tripartition blend with Mahuva biodiesel (MBD). In author's investigation the physicochemical properties of different tripartition blend fuels were determined like; 80% diesel, 15% BD, 5% ethanol (D80 BD15 E5) and another is 70% diesel, 25% BD, 5% ethanol (D70 BD25 E5) etc. The obtained propertieswere compared with that of diesel fuel for their suitability as an alternative fuel in compression ignition engine.

The experiment is conducted using eight test fuels blends such as, neat diesel (BD 0), 20% mahuva biodiesel blend with diesel(BD 20), a fuel containing 30% mahuva biodiesel blend with diesel (BD 30) and 40% mahuva biodiesel blend with diesel (BD 40). Remaining tripartition test fuel blends include D: BD: E (diesel, mahuva biodiesel and ethanol) in the ratio 80:15:5, next D: BD: E in the ratio 75:25:5, next D: BD: E in the ratio 60:35:5 and at last D: BD: E in the ratio 40:30:30. Experimental work was conducted on a single cylinder, four stroke,water cooled, compression ignition direct injection diesel engine with no modification in engine.

All tests were performed at constant speed of 1500 rpm and at seven different loads i.e. 0 kg, 2.0 kg, 4.0 kg, 6.0 kg, 8.0 kg, 10 kg and 12 kg. Property analysis of tripartition fuel were investigated and compared with diesel fuel.

6. Research Analysis and Experimental Outcomes

Experimental out comes related to property analysis of tripartition fuel blend

i) Density

Density is an intrinsic property of fuel which directly affects the engine performance. Atomization of fuel and combustion pattern also depends on density. Usually increment in density results more fuel flow resistance causes higher fuel viscosity, resulting poor fuel injection.

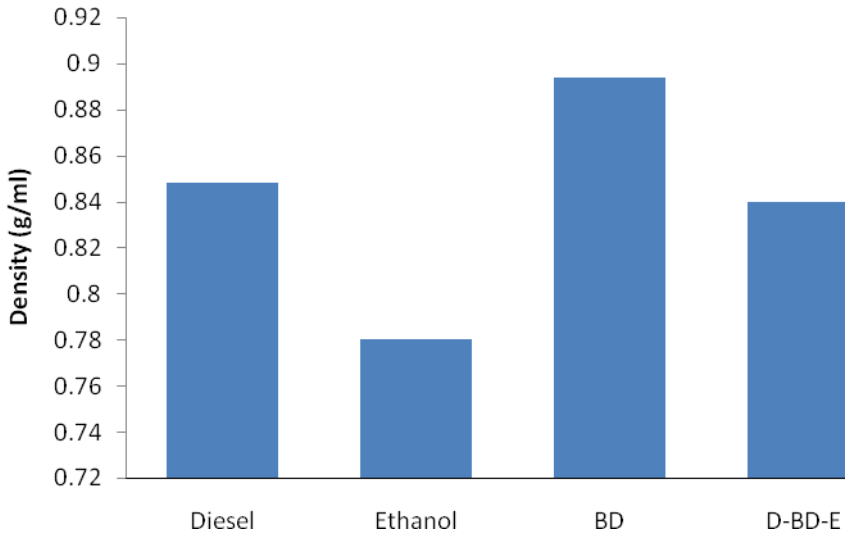

Fig. 6.1 Density of different test fuel samples

Figure 6.1 shows the densities of diesel fuel, ethanol, mahuva biodiesel and tripartition fuel blend (D-BD-E) are 0.848, 0.780, 0.894 and 0.840 g/ml respectively. Graph shows that density of ethanol is inferior to the diesel fuel; whereas density of the

mahuva biodiesel is on higher side than plain diesel. Tripartition fuel blend comprising diesel, mahuva biodiesel and ethanol density is slightly lower side than plain diesel fuel or approximately close to diesel fuel. Therefore above tripartition fuel blend can be considered as an alternative fuel in diesel engines. Density of fuel also affects power output of engine because of change in injected fuel quantity.

ii) Kinematic viscosity

Viscosity is also another important fuel characteristic which affects droplet size, atomization and finally combustion characteristics. Each engine works on certain given range of fuel viscosity. Less viscous fuel may create leakage problems while more viscous fuel may create fuel atomization problem resulting incomplete combustion and cold starting issue especially during winters.

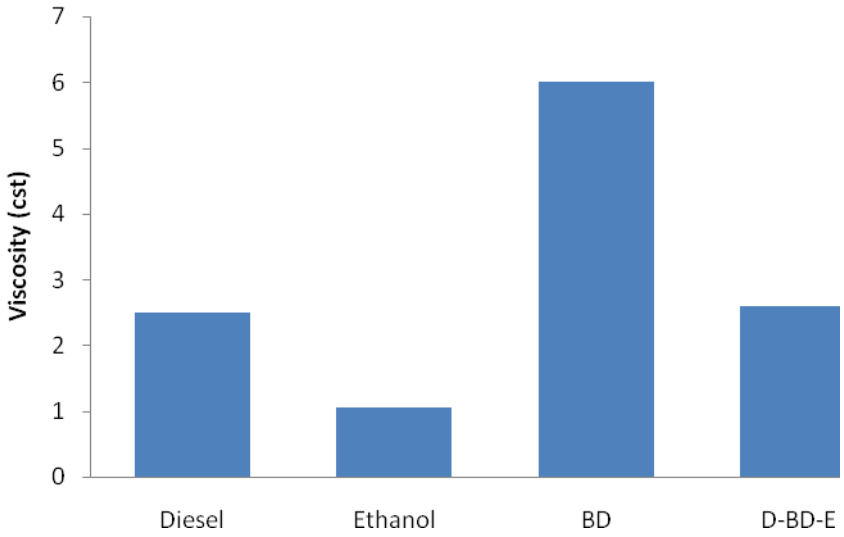

Fig. 6.2 Kinematic viscosity of test fuel samples

Figure 6.2 shows the viscosities of diesel fuel, ethanol, mahuva biodiesel and tripartition fuel blend of diesel , biodiesel and ethanol are 2.5, 1.06, 6 and 2.6 CST respectively. The lower viscosity of ethanol is compensated with higher viscosity of mahuva biodiesel. Therefore tripartition fuel blend viscosity comes to closer range of plain diesel fuel. On a contrary note plain mahuva biodiesel viscosity is much more so not suitable as fuel for diesel engine. So finally tripartition fuel blend is more suitable as an alternate fuel for diesel engine.

iii) Gross calorific value

Gross calorific value is determined by bomb calorimeter in which fuel sample is heated and because of burning heat is released , is measured while measuring ho water temperature. Figure 6.3 indicates the gross calorific values of diesel , ethanol, mahuva biodiesel and tripartition fuel blend are 42600, 26800, 39120 and 39891 kJ/kg.

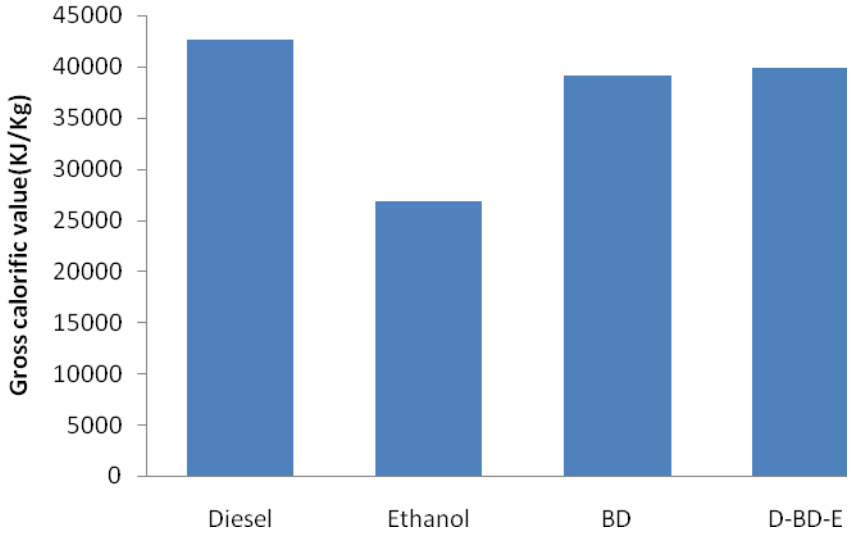

Fig. 6.3 Gross calorific values of test fuels

Figure 6.3 depicts gross calorific value of ethanol and mahuva biodiesel is less than plain diesel but tripartition fuel blend gross calorific value is nearer to plain diesel fuel. Gross calorific value directly affects output. Therefore tripartition fuel blend can be alternate fuel for diesel engine maintaining almost same power output as diesel engine.

IV) Flash Point

Flash point indicates about the temperature at which vapor pressure reaches to lower flammable limits. For safe transportation and storage purpose higher flash point fuels are preferred. Flash points of diesel fuel, ethanol, mahuva biodiesel and tripartition fuel blend are 78, 13, 157 and 20^0C respectively.

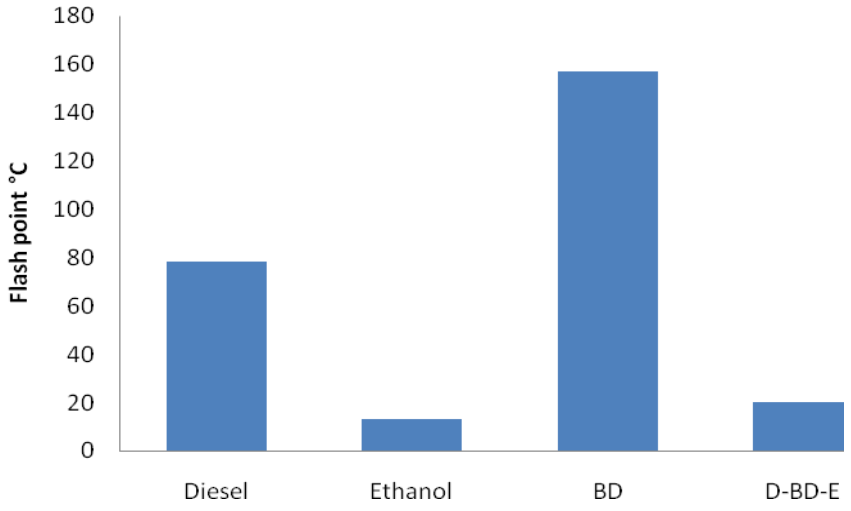

Fig 6.4 Flash point of different test fuels

Ethanol has very low flash point resulting which tripartition fuel blend also have lower side flash point. Special containers are needed for its storage and extra care is required during transportation as well.

V) Cetane number

Figure 6.5 indicates low cetane number of ethanol while mahuva biodiesel has high cetane number. As per IS or ASTM standards diesel fuel should have cetane number in

the range of 40 to 45. Therefore other fuels individually can't be considered as alternate fuel to diesel.

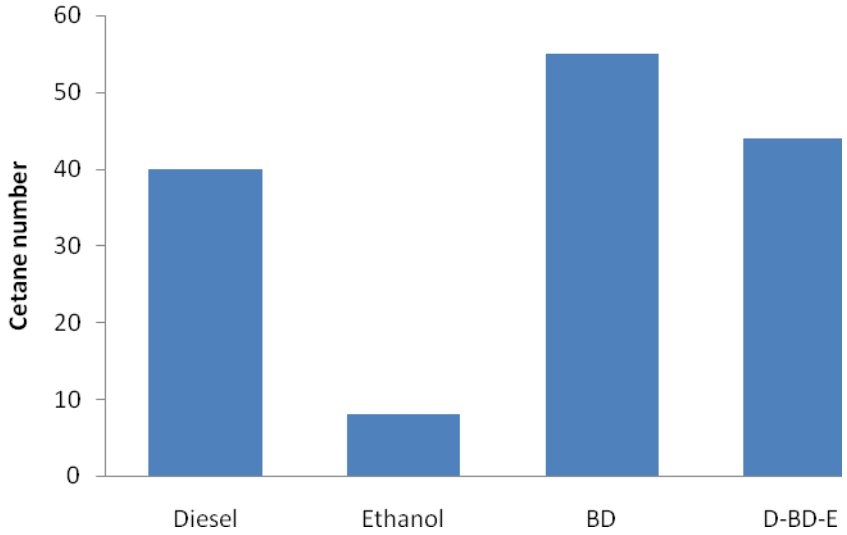

Fig. 6.5 Cetane number of different test samples

Figure 6.5 indicates cetane number of diesel fuel, ethanol, mahuva biodiesel and tripartion fuel blend are 43, 8, 55 and 44 respectively.

Lower cetane number affects the combustion characteristics of the fuel. Here blend of mahuva biodiesel with ethanol came almost in the range of similar to plain diesel engine. Therefore tripartition fuel blend can be considered as alternate fuel for diesel engine.

VI) Pour Point

Figure 6.6 indicates the pour point of diesel fuel, ethanol, mahuva biodiesel and tripartition fuel blend are 5^0C, -8^0C, 10^0C and -10^0C respectively. Mahuva biodiesel has pour point on higher side, on a contrary ethanol has very less pour point. Tripartition fuel blend has lower pour point because of ethanol mixing.

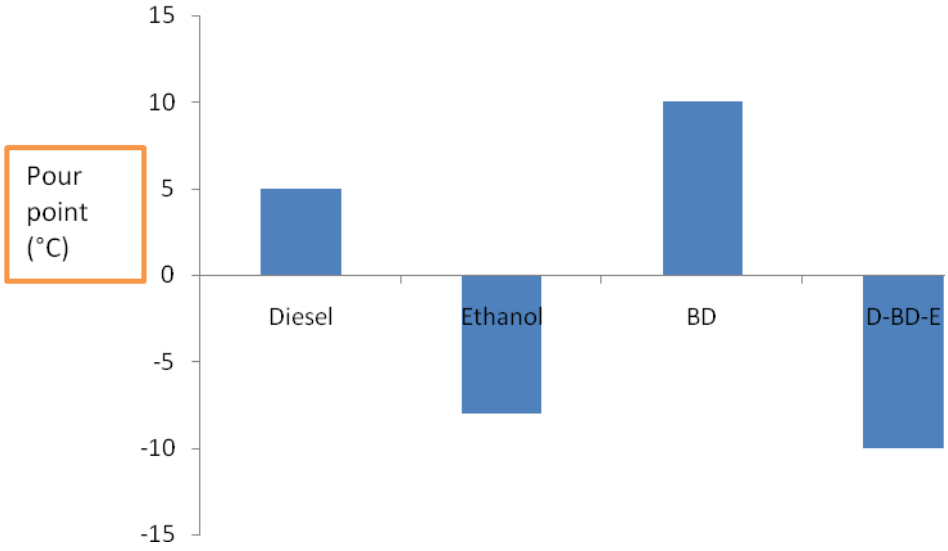

Fig. 6.6 Pour point of different test fuel samples

Based on experimental observation fuel properties of tripartition fuel blend is close to plain diesel fuel. Therefore tripartition fuel blend can be used as alternate fuel for diesel engine to observe engine performance and emission characteristics.

Conclusions

With reference to above detailed discussion on available sustainable measures it clearly indicates that in the recent past the emission control technologies for motor vehicles have experienced dramatic improvements, driven by increasingly stringent emission standards. A single cylinder, four-stroke, 1500 rpm, water-cooled, direct injection CI engine can also be operated on BD10 and BD20 without any major modifications. The conclusions from the work are as follows:

- The density of the ethanol (0.778 g/ml) was lower than the diesel fuel (0.846 g/ml), whereas the density of the MBD(0.895 g/ ml) is much higher than that of the diesel fuel, so these bio fuels cannot be used alone in the compression ignition engines (CI). The tripartition fuel blends (D: MBD: E) have density nearer to the diesel fuel which can be used as an alternative fuel in diesel engines.
- The gross calorific values of diesel, ethanol, MBD, D-MBD-E are 41596 kj/kg, 26804 kj/kg, 39124 kj/kg, 39898 kj/kg respectively. The tripartition fuel blend calorific value is close to neat diesel fuel. Therefore tripartition fuel blend is suitable alternative fuel to get same power output as diesel engine.
- The calorific value of mahua oil was observed as 88.29% of diesel on weight basis and 96.26% on volume basis. The calorific value of mahua oil was found nearer to diesel fuel in comparison with other liquid fuel options like ethanol and methanol.
- The viscosity of diesel (2.7), ethanol(1.04), MBD(6.2), tripartition fuel blend(2.6).
- The cetane number of ethanol is 9, MBD has higher cetane number 55 and tripartition fuel blend have cetane number (43-44) that is in the same range of diesel fuel. Therefore tripartition blends can be used as an alternative fuel in diesel engine.
- The pour point and cloud points of the tripartition fuel blends were better values than the other combination fuels.
- Results cleared that physical and chemical properties of the tripartition blend fuels were more or less same as that of the diesel fossil fuel, therefore tripartition fuel can be effectively used as an alternative fuel.
- Few untoward fuel properties, like high viscosity and low density, which cause problems in poor fuel atomization, incomplete combustion and ring carbonization in the combustion chamber. These problems can be overcome by blending.

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