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INVESTIGATIONS ON FUEL PROPERTIES OF TERNARY MIXTURE OF ETHANOL, BIO DIESEL FROM ACID OIL AND PETROLEUM DIESEL TO EVALUATE ALTERNATE FUEL FOR DIESEL ENGINE

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ABSTRACT

Ethanol and biodiesel are two potential alternative fuels and ethanol can be used with biodiesel to extend the availability of diesel. In this work Acid oil, a byproduct of vegetable oil refineries has been investigated as a source of biodiesel as it is economical and readily available. Fuel properties of biodiesel produced are compared with standard diesel fuel. Blends of ethanol, biodiesel and diesel are prepared maximizing the biodiesel content to 60%. In order to ascertain the applicability of blends as fuel, properties such as density, kinematic viscosity, calorific value, flash and fire point, cloud and pour point of stable blends have been determined as per ASTM standards. Cetane index is calculated using four variable equation method. Results suggests that all properties are in accordance with the stipulated standard values of biodiesel.

KEYWORDS: Acid Oil, Biodiesel, Diesohol, Ethanol, Biodiesel, Diesel Stable Blends, Fuel Property Variation

INTRODUCTION

Unsustainable demands of petroleum fuels, increased global warming threats and environmental degradation matters have necessitated for development and adaptation to ecofriendly and renewable type of energy resources all over the world. Biodiesel and bio ethanol are two such alternatives which are being projected as substitutes to diesel and gasoline fuels. Their adoptability to existing engine designs, reduced toxic emissions, comparable engine performances and choice for wide variety of feed stocks have made them attractive and have encouraged many countries to initiate several biofuel developmental programmes in their respective zones. Though biodiesel and ethanol are attractive, but are uneconomical at present, mainly due to their high costs of feed stocks and technological constraints employed during manufacturing.

To reduce the dependency of imported petroleum fuels, most of the biofuels produced at present are blended with diesel/gasoline and are used as economic and energy drives. Amongst the blends studied,

- Blends of Diesel with Biodiesel (BD blends)
- Blends of Diesel with Ethanol (Diesohol)
- Blends of Ethanol, Biodiesel and Diesel (EBD blends)

Have received more attention in recent years. However studies of many researchers have indicated that blends of diesel with biodiesel and diesel with ethanol increases NO_X formation at different operating loads. Adding biodiesel to diesel and ethanol have shown reduced hydro carbon and NO_X emissions and also studies confirmed that blends offer substantial reduction of carbon monoxide (CO), unburnt hydro carbons (UHC) and dangerous particulate matters (PM) than petroleum fuels [1,2]. Blending of biodiesel and alcohol with petroleum fuels not only reduces imports of petroleum but also offers remunerative price for biomass feed stock and creates additional employment at rural locations, thus supporting agriculture and our national economy.

Biodiesel which is a mixture of alkyl (Eg. Methyl, ethyl) ester of fatty acids is made from a wide range of vegetable oils, animal fats and used cooking oil and also from waste oil by using trans-esterification process. Moreover, biodiesel can be used not only as an alternative to petro diesel, but also as an additive for Diesohol- a blend of alcohol (ethanol) with regular diesel. [3, 4]

Ethanol is used as an alternative fuel as it is a renewable fuel which can be produced from many types of domestic agricultural products such as corn, sugarcane, sugar beets, molasses or cassava, waste biomass materials etc. It can reduce the petroleum fuel imports and can also increase former's income [1,5]. Biodiesel can also be produced from free fatty acid mixture, acid oil which is readily available as by product at most of the vegetable oil refinery sites. Development of biodiesel from the source enhances the support price of oil seed and thereby encourages the agricultural activities, which influences our national economy and will help to reduce our external dependence for energy needs. [6]

Generally ethanol blended with diesel (diesohol) need no major engine modifications [7] however ethanol and diesel are inherently immiscible and therefore needs an effective emulsifier to produce homogenous fuel. The emulsifier would reduce interfacial tension force leading to emulsion stability. Biodiesel is known to act as an emulsifier due to its slight polarity and long fatty acid carbon chain has potential to improve miscibility of ethanol and diesel over limited range.

It is evident that further studies are necessary in both diesohol production and utilization. Major importance should be given for producing biodiesel from raw materials that are available economically and more attractive system is the production and usage of fuel containing biodiesel and ethanol which can be produced abundantly in India.

The objective of this work is i) To produce biodiesel from acid oil ii) To compare fuel properties of biodiesel thus produce with standard specifications iii) Blending of biodiesel with diesel and ethanol and iv) To study the variations of fuel properties of stable blends.

MATERIALS AND METHODS

Experiments were conducted to study the phase behavior and to determine the fuel properties of a three components fuel system comprising Ethanol – Biodiesel and Diesel. The acid oil sample is used to produced biodiesel was procured from M/s Murugharajendra Oil Industries Pvt. Ltd. Chitradurga, Karnataka, India, Which is a medium scale oil processing industry. Biodiesel is produced by this acid oil using a new type of process which is developed at the research centre where esterification reaction is carried out by incorporating the principles of Extractive Distillation (ED) and by the use of operations like Rectification (R), Reflecting (R) and Recycling (R) for the excess methanol used in the process. The whole process is abbreviated as ED3R esterification process.

Diesel sample used for the present study was obtained from local Indian oil outlet.

Ethanol (99.9%) pure used for the present study was obtained from M/S Samson's Distilleries, Duggavati, Davangere District, Karnataka, India.

The fuel properties of these three components ie., Ethanol-Biodiesel and Diesel were determined by following standard test methods to ensure their compliance to standard specifications. Blends of Ethanol-Biodiesel and Diesel were prepared by mixing into a homogeneous mixture using a magnetic stirrer. To study the effect of three component ratios on the fuel properties, ten blends Ethanol-Biodiesel and Diesel were prepared, which are obtained by mixing Ethanol Biodiesel and Diesel by volume by varying the ethanol component from 0% to 20% as shown in table 2. Laboratory tests were then carried out using ASTM tests standards to determine the properties such as the density, kinematic viscosity, calorific value, flash point, fire point, cloud point, pour point and cetaneindex. All analytical instruments used for the present studies were confirming to ASTM and Indian Petroleum Institute (IPI) specifications.

RESULTS AND DISCUSSIONS

Fuel properties of the blends of different proportions are presented in Table 2. As the structure, size and types of compounds associated with Ethanol Biodiesel and Diesel are completely different they exhibit their own fuel properties. The following are the important observations made from fuel property studies.

Table 1: Properties of Three Component Fuels

Property	Method	Ethanol	Biodiesel	Diesel
Density (kg/m^3)	ASTM D-4052	789	857	819
Kinematic viscosity (mm^2/s)	ASTM D-445	1.20	5.55	2.94
Calorific value (kJ/kg)	ASTM D-2015	26843	41577	44189
Flash point (°C)	ASTM D-9390	17	97	57
Fire point (°C)	ASTM D-9390	34	113	64
Cloud point (°C)	ASTM D-4052	-7	0	2
Pour point (°C)	ASTM D-2500	≤35	-3	-16
Cetane index	ASTM D-613	8	57	52

Table 2: Properties of Blends of EBD (% by Volume)

	Blends of Ethanol :Biodiesel: Diesel (% By Volume)									
Properties	**0:60:40**	**2:60:38**	**6:60:34**	**8:60:32**	**10:60:30**	**12:60:28**	**14:60:26**	**16:60:24**	**18:60:22**	**20:60:20**
Density (kg/m^3)	839.2	836.3	834.2	831.4	828.4	826.9	825.1	822.9	819.9	817.6
Kinematic viscosity (mm^2/s)	5.36	5.16	4.78	4.58	4.36	3.98	3.78	3.36	3.15	3.07
Calorific value (kJ/kg)	43862	43372	41250	40365	39781	38992	38149	37822	36667	35863
Flash point (°C)	81	76	72	69	66	62	60	56	54	51
Fire point (°C)	93	80	77	73	70	68	65	60	57	54
Cloud point (°C)	1	-1	-2	-2	-2	-3	-3	-4	-5	-5
Pour point (°C)	-4	-4.5	-5	-5	-5.5	-7	-7.5	-9	-11	-13
Cetane index	54.98	54.28	52.30	51.45	50.53	49.25	48.86	47.53	46.10	44.93

DENSITY

Density of different fuel blends by varying ethanol and diesel proportions keeping biodiesel proportion constant are as shown in Table 2. It can be observed that density of biodiesel is higher when compared to density of diesel and ethanol and density decreases with increase in percentage of ethanol due to the fact that ethanol has lower density and will lower the density when mixed with diesel and biodiesel. Higher density is not suitable as it leads to flow resistance. However the results of density variations of different blends shows the value are within acceptable limits. Figure 1 shows variations of density of different stable blends.

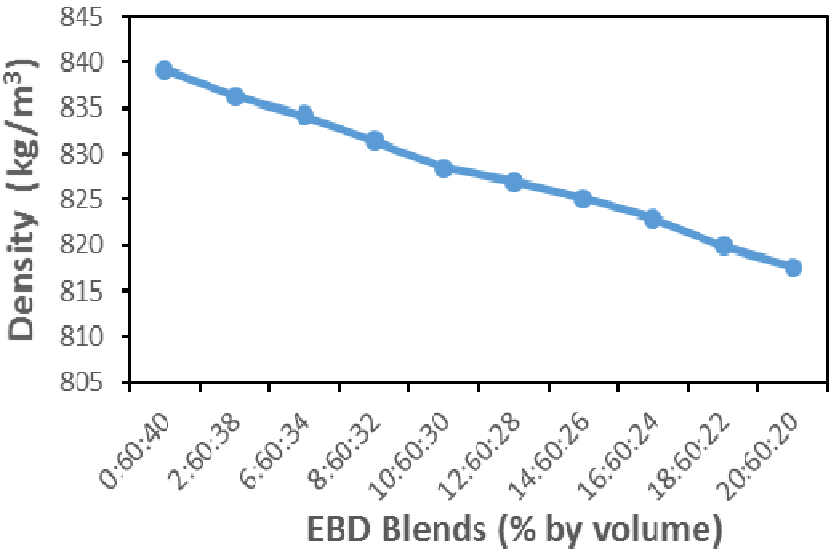

Figure 1: Variations of Density of EBD Blends

Kinematic Viscosity

The viscosity of fuels measured are as shown in Table 2. The viscosity of the blends decreases as the percentage of ethanol in the blend increases. This is mainly due to very low viscosity of the ethanol when compared to viscosities of biodiesel and diesel. Figure 2 shows the variations of viscosities with varying proportions of diesel and ethanol.

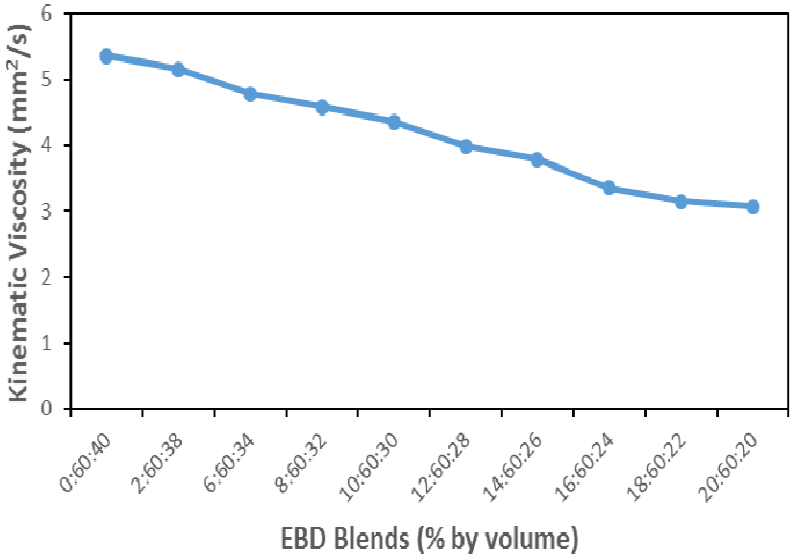

Figure 2: Variations of Viscosity of EBD Blends

Calorific Value

Calorific value of the fuel is one of the most important property as it has a direct influence on power output of an engine. The results shows that calorific value of mixture of diesel and biodiesel decreases with increase in ethanol percentage. However heating values of blends containing less than 10% of ethanol were not much different from that of conventional diesel and the calorific value of tested fuel blends were quite high so that better combustion characteristics can be obtained when compared to other vegetable oils [12, 13].

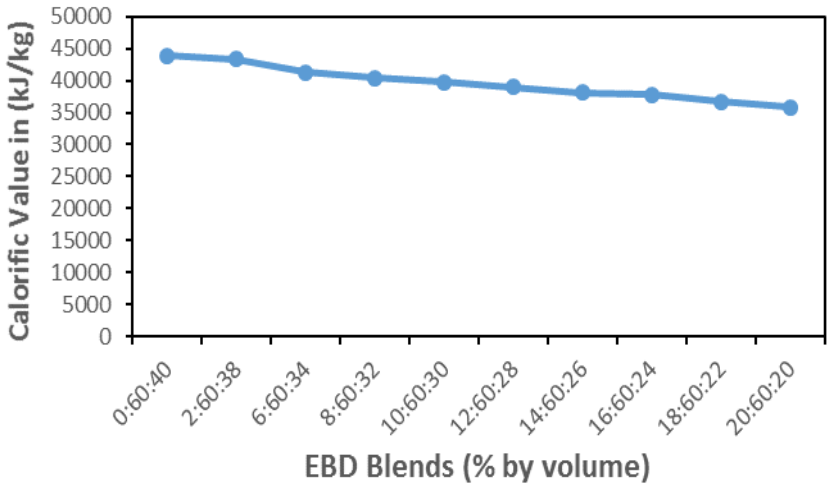

Figure 3: Variations of Calorific Value of EBD Blends

Flash and Fire Point

Flash and fire points of biodiesel, diesel and ethanol are as shown in Table 1. As biodiesel is produced from acid oil and fatty acids of acid oil are of higher molecular weights (250 to 300) they are non volatile. They give out sufficient vapors at elevated temperatures to form a combustible mixture with air hence flash and fire points of biodiesel are much higher than diesel and ethanol. As the flash and fire points of ethanol are very less when compared to diesel and biodiesel, the flash and fire points of the blends decreases with increase in percentage of ethanol. But as the percentage of the biodiesel in blends is higher i.e., 60%, with 20% of ethanol, the flash and fire points of the blends are slightly lower than the flash and fire points of the conventional diesel which makes it as a convenient fuel as that of diesel.

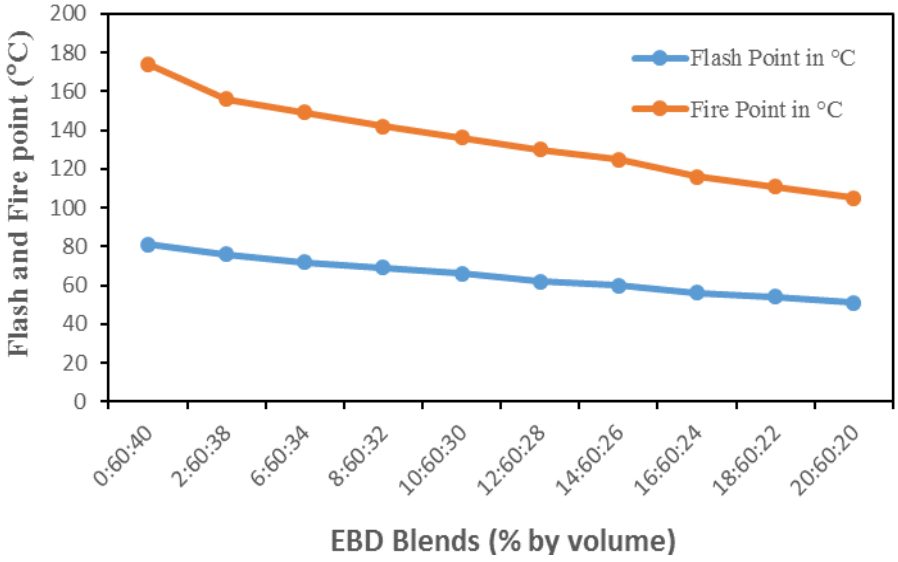

Figure 4: Variations of Flash and Fire Points of EBD Blends

Cloud and Pour Point

The cloud and pour points of three component fuels are presented in Table 1, and those of blends are presented in Table 2. The cloud point of fuel when compared to cloud point of blends with increased percentage of ethanol is less but

the pour point of biodiesel is higher than diesel due to increase in viscosity at reduced temperatures which ceases the oil to flow. However the presence of ethanol in the blends affected the pour point. Blends with less than 10% of ethanol were found to have minimum variations in pour points as the percentage of biodiesel is constant. Blends with 12%, 14%, 16%, 18% and 20% of ethanol found to have lower pour points due to the fact that the ethanol delayed the degree of coalescent of the blends despite of miscibility of ethanol, biodiesel and diesel.

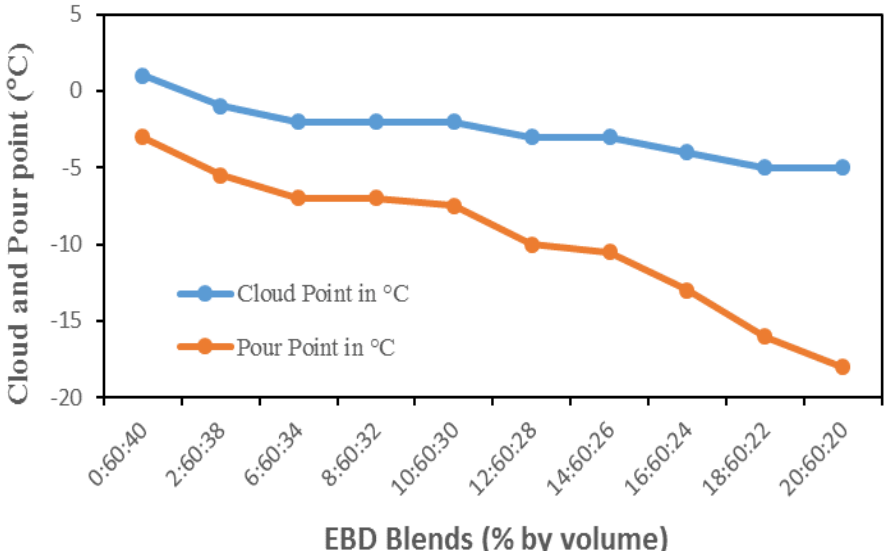

Figure 5: Variations of Cloud and Pour Points of EBD Blends

Cetane Index: Cetane Index of biodiesel is higher when compared to cetane index of diesel. But cetane index of ethanol is very less. Hence the cetane index of blends decreases with increase in percentage of ethanol. But as a percentage of biodiesel is constant at 60% it enhances the cetane index of blends. The blends containing less than 10% of ethanol are having higher cetane index than that of diesel and the blends with higher percentage of ethanol are having cetane index within the acceptable limits of standard specifications. So that better engine performance can be obtained.

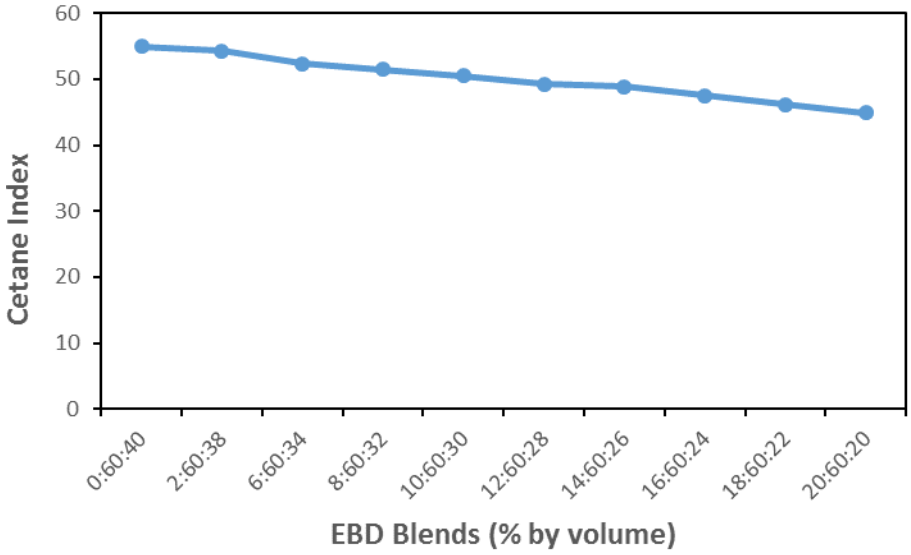

Figure 6: Variations of Cetane Index of EBD Blends

CONCLUSIONS

Investigations for stability and fuel properties of ethanol-biodiesel and diesel and their blends are carried out to evaluate the potential for using biodiesel and diesohol blends as an effective alternate fuel for diesel engines. The following conclusions could be drawn from the present study.

- Biodiesel produced from acid oil could be used as an effective additive for diesel and ethanol emulsions. For diesohol production absolute ethanol (99.9 % pure) should be used to prevent phase separation.
- Density and viscosity of all the blends were found to be under standard limits of diesel fuel.
- Because of higher percentage of biodiesel in blends the flash and fire points recorded are comparatively higher compared to diesel fuel for blends containing less than 10% ethanol and found to be closure to diesel fuel for blends with more than 10% ethanol.
- Lower cloud points were recorded for all blends compared to cloud points obtained for diesel fuel alone. However pour point decreased with increase in ethanol percentage in blends but found to be lower than diesel fuel.
- Calorific value of blends were lower than that of diesel but the difference were not significant for the blends containing less than 5% of ethanol.
- In general blends containing higher percentage of ethanol are having very close fuel properties compared to diesel fuel since the major component is biodiesel (60%) except calorific value owing to lower calorific value of ethanol.

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