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Investigation on Utilization of Ethanol – Bio-diesel blend as Substitute Fuel to CI engines

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Abstract

Energy is essential for existence, economic growth and social development of any country. Its consumption is well accepted tool for judgment of development status of any country. India's domestic supply of crude oil satisfies only 22% of demand and rest is met by imports. Hence attempts are essential to reduce dependence on imported fossil fuels. An attempt was made to investigate proper method for utilization of ethanol–bio-diesel blend as substitute fuel to compression ignition engines. Test fuels were prepared by mixing ethanol and bio-diesel in various proportions using ethyl acetate as surfactant. Stability status of prepared fuels and selected fuel properties were determined using standard methods. Prepared fuels were utilized to energize a 3.73 kW Kirloskar make, constant speed, four stroke single cylinder direct injection CI engine and engine performance and exhaust emission parameters were recorded. The paper describes the results of the investigation based upon experimental observations.

1. Introduction

Energy is an essential for existence, attaining betterment in quality of life, economic growth and social development of a country. Energy consumption is worldwide well accepted tool for assessment of development status of any country. Since, their exploration, fossil fuels have been an important conventional energy source. The increasing trend of industrialization and modernization of services are continuously enhancing the energy demand at a much faster rate in almost every part of Glob. Majority of developing countries, in spite of their crumbling economy, are forced to import fossil fuels to satisfy their energy demand. Consequently, these countries have to spend a major part of their export income to buy petroleum products *[Hanbey Hazar, 2010]*.

India consumes only 4 % of World's crude oil annual supply and 2 % natural gas *(Pathak, 2013) but supports* 17 % of World population. The reserve of own crude oil and natural gas are grossly inadequate for the country and it is heavily dependent on imports to meet the present needs of these fuels. The country ranks sixth in terms of energy demand accounting for 3.5 % of global energy demand. Energy consumption level is likely to increase further considering the high growth in GDP (7-8% annually), growing population and increasing industrial & agricultural activities. Oil provides energy for 95% of transportation and it increasing steeply with increase in vehicular fleets. The demand of diesel in India increased to 66 MT during 2011-12 from 40 Mt. The domestic supply of crude oil satisfies only 22% of the demand and rest is met by imports. The crude prices and availability are subject to great volatility depending upon the international situation and so attempts are essential to reduce dependence on imported fossils. Now a giant question is waiting that how to cater the increasing energy demand with sustainable environment?

The compression ignition engines are widely used in the transport sector, a standby power unit in industries and in agricultural fields due to their long life, reliability and fuel economy. Due to the increasing energy utilization trend in the recent years, scarcity of diesel to meet the enhancing demand is being faced. In addition, the stringent governmental regulations on emission control forcing for search of environmentally benign alternative fuels which are renewable *[Hansen, et. al., 2005]*.

Bio-fuels seem to be an appropriate option to deal with the above mentioned complex situation. Bio-fuels are an ideal alternative to dwindling fossil resources. The use of bio-fuels that are based on renewable resources has several advantages *[Lettens et al., 2003]*. These are renewable in nature and environmentally safe as compared to fossil fuels.

Among the feasible alternative fuels, bio-ethanol, biodiesel, diesohol and to a lesser extent pure vegetable oils are considered as most promising bio-fuels. Out of these, biodiesel and diesohol have received much attention in recent years for diesel engines and could be one remedy in many countries to reduce their dependence on fossil oil.

Biodiesel is an alkyl (e.g. methyl, ethyl) ester of fatty acids produced from a wide range of vegetable oils, animal fat and used cooking oil via the tranesterification process. Biodiesels are used because of their similarity to diesel oil, which allows the use of biodiesel-diesel blends in any proportion. 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 *[Ribeiro, et al., 2007]*.

Diesohol is a homogeneous blend of an alcohol and diesel. Among the various alcohols, Ethanol is the most preferred fuel because it is renewable and produced from various agricultural feed stocks. It is an alcohol most often chosen because of the ease of production, can be obtained from various kinds of biomass such as maize, sugarcane, sugar beet, corn, cassava, red seaweed etc., relatively low-cost and low toxicity *[Lapuerta, et al., 2007]*. Ethanol is used as an alternative fuel, a fuel extender and an octane enhancer. It is a low cost oxygenated compound with high oxygen content (34.8%).

Biodiesel and ethanol have many advantages over regular diesel as renewable and domestically produced energy resources. Moreover, they are recognized as environmentally friendly alternative fuels because previous studies have shown that there is a substantial reduction of CO, unburned hydrocarbons and particulate matter emission, when they are used in conventional diesel engines *[Li et. al., 2005; Shi, et. al, 2005 and Srivastava, et. al, 2000]*. If efforts are made to blend both renewable fuels, i.e. biodiesel and bio-ethanol, the inherent environmental benefits available with both fuels could be utilized in sustainable manner. If such a stable blend of both the contender fuels is successfully prepared then an appropriate fuel formulation may be available to combat the environmental deterioration problems as well energy shortages as well. Since, these fuels are produced from renewable sources and could be produced domestically so the dependency on fossil liquid fuels is likely to be reduced significantly. Besides, there would be more employment generation in rural sector due to increased involvement of man power in production, processing and handling of these fuels. Ultimately these factors would lead to improvement in socio-economic conditions of Indian rural sector. In view of the above facts, an investigation was undertaken on utilization of ethanol – bio-diesel blend as substitute fuel to CI engines.

2. Review of Literature

Biodiesel has been used not only as an alternative fuel, but also an additive for diesohol [*Fernando, et al., 2004 and Cheenkachorn, et al, 2004]*. This homogeneity is due to the fact that the biodiesel can act as an amphiphile and form micelles that have nonpolar tails and polar heads. These molecules are attracted to liquid/liquid interfacial films and to each other. These micelles acted as polar or non-polar solutes, depending on the orientation of the biodiesel molecules. When the diesel fuel was in the continuous phase, the polar head in a biodiesel molecule oriented itself to the ethanol, and the non-polar tail was oriented to the diesel *[Kwanchararerareon, et al, 2007 and Violeta, et al., 2005]*.

X.Shi et al., 2005 used 20% methyl soyate as additive with diesel ethanol blend to prepare a stable fuel blend and the performance and emission test on a multi cylinder variable speed engine shown significant reduction in smoke and particulate emission.

Violeta et al., 2005 conducted solubility test on multi-component biodiesel fuel system. They found that Rapeseed oil ethyl and methyl esters are soluble in ethanol and diesel without limits and the addition of ethanol increases the inter-solubility of ethanol and fossil diesel.

Pang et al., 2006 reported that use of biodiesel- ethanol-diesel blend could slightly increase the emissions of carbonyls and NO_X but significantly reduce the emissions of PM and THC.

Lapuerta et al., 2008 used E10 blend without any additives and conducted performance test on stationary engine test bed. They found improvement in the efficiency of the engine and reduction in particulate matter emission. They suggest using cetane number enhancers and co-solvent additives for the blend stability and better performance and emission reduction.

Selvan, et al., 2009 used biodiesel (Jatropha Methyl Ester) produced through transesterification as a bridging agent between diesel and ethanol to prevent phase separation. It was reported that phase separation of ethanol-diesel blends can be prevented using desired quantity of biodiesel (Jatropha methyl ester) as additive. The stability of the blend increases with the increase in the temperature. 10% biodiesel by volume prevents the phase separation at 30^0C for the blends E5, E10, E15, E20 and E25. The brake thermal efficiency of the engine fueled with diesohol blends is slightly higher or equal with lower ethanol and higher biodiesel proportion and found decreases with the increases in percentage of ethanol at the compression ratios 15, 17 and 19. Highest brake thermal efficiency is observed as 26.15% for neat diesel under the compression ratio of 17 at the brake mean effective pressure of 0.44MPa, whereas the lowest brake thermal efficiency is observed as 22.61% for the E25 blend under the compression ratio of 15 under the same loading condition. The least CO emission is observed as 0.37% for the E25 blend at the compression ratio of 15 and the highest CO emission is 0.88% for neat diesel under the compression ratio of 17 at the bmep of 0.44MPa. The least hydrocarbon emission is found as 110 ppm for the E5 blend under the compression ratio of 19 and highest as 198 ppm for the E25 blend under the compression ratio of 17 at the bmep of 0.44MPa.

Pugazhvadivu, 2009 studied the effect of ethanol addition to biodiesel by conducting experiments on a single cylinder diesel engine using B25, B50, B75 and B100 biodiesel diesel blends with 5% and 10% ethanol addition. It was reported that the addition of ethanol to biodiesel diesel blends did not alter the engine performance significantly. The engine produced lower NO_X and smoke emission with ethanol addition.

Weerachanchai, et al. 2009 studied the phase behaviors and fuel properties of bio-oil-diesel-alcohol blends using bio-oil derived from palm kernel pyrolysis by blending it with diesel fuel and alcohols. It was reported that the alcohol types showed a significant influence on the phase characteristics with palm kernel bio-oil-diesel-butanol system giving larger soluble area than that of palm kernel bio-oil-diesel-ethanol system.

Torres et al., 2010 determined the physical and chemical properties of Ethanol- Biodiesel blend for diesel engine. It was reported that cold weather properties were improved by adding ethanol to biodiesel. In general, the results show that ethanol in biodiesel influences beneficially the most important fuel properties of the blended fuel. Potentially, this may offer a possibility to impure engine characteristic. However, to confirm this assumption, further engine tests have to be prepared.

Above presentation on the various aspects of use of ethanol diesel blends as substitute fuel for CI engines reveal that same could be used as alternative fuels for diesel engines with no engine modifications required *[Ajav, et. al, 2002]*. Because all automotive fuels are required to be a clear, single-phase liquid, various commercial surfactants are used as emulsifiers to form ethanol-diesel emulsions. Typically, these surfactants are added at a concentration of e5%. The literature suggests that the various commercially available surfactants include alkanols, decaglycerol mono-oleate (MO750), and alkanolamides. However, the performance of such surfactants, in terms of phase behavior or phase stability, has not been reported. Also, to prevent engine and fuel system damage, the phase behavior of alternative fuels and regular fossil fuel blends should be investigated extensively under differing conditions. Taking into account the environmental considerations, the more attractive system is the production and usage of fuel containing biodiesel and ethanol, which can both be produced in India.

3. Materials and Methods

3.1. Fuels and Surfactant

The bio-diesel was manufactured in the Bio-fuel Laboratory of the Agricultural Energy & Power Division at the Central Institute of Agricultural Engineering, Bhopal with the available bio-diesel production unit (Fig. 1) by following standard methods and techniques using Karanj oil as substrate and alkaline methanol as medium of transesterification for biodiesel production. The Cympron make anhydrous ethanol procured from local market was utilized for preparation of various test fuels. Ethanol of 170°, 180° and 190° proof were prepared by adding distilled water into anhydrous ethanol in the required amount. The details of prepared aqueous ethanol are presented in Table 1. Various blends of ethanol and biodiesel were prepared in the Bio-fuel Laboratory of the CIAE, Bhopal using ethyl acetate (($CH_3COOC_2H_5$) as surfactant. The details of preparations are presented in Table 2 through 5. The prepared fuels which were found stable after 24 h from time of preparation were tested under varied room temperature of 35 and 45° C to observe the wide range temperature stability. The sample were kept for 24 h after that the temperature was raised to 35 and 45° C and the same sample were kept for 24 h in each room temperature to observe the stability by visually inspecting the occurrence of phase separation if any.

Table 1. Details of Aqueous Ethanol Preparation

S. No.	Ethanol Proof, ⁰	Ethanol Content, %	Water Content, %
1	200	100	0
2	190	90	10
3	180	80	20
4	170	70	30

Figure 1. Bio-diesel production unit

Table 2 Details of alcohol-biodiesel substitute fuels prepared using 200 proof ethanol and ethyl acetate surfactant

S. No.	Fuel Identity	Fuel Constituents, %			Biodiesel Replacement, %
		Ethanol	Ethyl Acetate	Bio-diesel	
1	200^{0}-10/0/90	10	0	90	10
2	200^{0}-15/5/80	15	5	80	20
3	200^{0} 20/10/70	20	10	70	30

Table 3 Details of alcohol-biodiesel substitute fuels prepared using 190 proof ethanol and ethyl acetate surfactant

Sl. No.	Fuel Type	Fuel Constituents (%)			Biodiesel Replacement (%)
		Ethanol	Ethyl Acetate	Bio-diesel	
		10	1	89	11
1.	190^{0}-10/1/89	10	3	87	13
2.	190^{0}-10/3/87	10	10	80	20
3.	190^{0}-10/10/80	10	22	68	32
4.	190^{0}-10/22/68	15	20	65	35
5.	190^{0}-15/20/65	15	23	62	38
6.	190^{0}-15/23/62	15	26	59	32
7.	190^{0}-15/26/59	20	5	75	25
8.	190^{0}-20/5/75	20	8	72	28
9.	190^{0}-20/8/72	25	9	66	34
10.	190^{0}-25/9/66	25	15	60	40
11.	190^{0}-25/15/60	30	10	80	30
12.	190^{0}-30/10/80	35	33	32	68
13.	190^{0}-35/33/32	35	37	28	72
14.	190^{0}-35/15/28	10	40	25	75
15.	190^{0}-35/20/25	10	1	89	11

Table 4 Details of alcohol-biodiesel substitute fuels prepared using 180 proof ethanol and ethyl acetate surfactant

Sl. No.	Fuel Type	Fuel Constituents (%)			Biodiesel Replacement (%)
		Ethanol	Ethyl Acetate	Biodiesel	
1.	180^{0}-10/10/80	10	10	80	20
2.	180^{0}-10/15/75	10	15	75	25
3.	180^{0}-10/25/65	10	25	65	35
4.	180^{0}-10/36/54	10	36	54	46
5.	180^{0}-15/20/65	15	20	65	65
6.	180^{0}-15/30/55	15	30	55	23
7.	180^{0}-15/39/46	15	39	46	54
8.	180^{0}-20/10/70	20	10	70	30
9.	180^{0}-20/41/39	20	41	39	61
10.	180^{0}-25/10/65	25	10	65	35
11.	180^{0}-30/15/55	30	15	55	45
12.	180^{0}-30/7/26	30	18	52	48

Table 5 Details of alcohol-biodiesel substitute fuels prepared using 170 proof ethanol and ethyl acetate surfactant

Sl. No.	Fuel Type	Fuel Constituents (%)			Biodiesel Replacement (%)
		Ethanol	Ethyl Acetate	Biodiesel	
1.	170^{0}-10/5/85	10	5	85	15
2.	170^{0}-10/7/83	10	7	83	17
3	170^{0}-10/43/47	10	43	47	53
5.	170^{0}-15/13/72	15	13	72	28
5.	170^{0}-15/15/70	15	15	70	30
6.	170^{0}-15/45/40	15	45	40	60
7.	170^{0}-20/15/65	20	15	65	35

8.	170^0-20/18/62	20	18	62	38
9.	170^0-20/20/60	20	20	60	40
10	170^0-20/52/28	20	52	28	72
11.	170^0-25/25/50	25	12	63	37
12.	170^0-25/27/48	25	27	48	42

3.2. Measurement of Fuels Properties

Various fuel properties of ethanol – biodiesel – acetate blends like relative density, API gravity, kinematic viscosity, flash & fire points, etc. were determined using standard equipment like pyknometer, viscometer (Fig. 2), flash point apparatus (Fig. 3), etc. respectively in accordance with standard procedures.

Fig. 2 Viscometer

Fig. 3 Flash & fire point apparatus

3.3. Engine Test Set-up

The engine experimental test set-up consisted of the test engine coupled to an eddy current dynamometer along with controller (Fig. 4). A SAJ-Froude make, EC-15 model dynamometer was used to load the engine. A Kirloskar make, constant speed, four stroke, single cylinder, direct injection compression ignition engine was selected for the study. Exhaust emissions were monitored with the help an exhaust analyzer (Fig. 5).

Fig. 4 Engine test set up

Fig. 5 Exhaust monitoring

3.4. Experimental Procedure

The performance test of the engine was conducted as per IS: 10000 [P: 5]:1980. Initially the engine was run on no load condition and its speed was adjusted to 1500 ± 10 rpm by adjusting the screw given with the fuel pump rack. The corresponding torque to be applied to the engine when delivering rated power (3.73. kW) at rated speed of 1500 rpm was calculated using following correlation.

$$\mathrm{kW} = \frac{N \times T}{9549.305}$$

where,

T = Engine Torque, N-m

N = Engine Speed, rpm

The calculated torque was considered at 100 % load on the engine and the engine speed was adjusted to 1500 ± 10 rpm at 100% load. The engine fueled with prepared fuels was tested 20, 40, 60, 80 and 100 % loads and various engine performance and exhaust emission parameters were recorded.

4. Results and Discussion

4.1. Stability of Prepared Fuels

The stability of micro emulsions was determined by observing the phase separation at room temperature after 24 hours of their preparation. Out of the fifty nine fuel preparations twenty two were found stable after 24 hours at room temperature (which varied between 35-45^{0}C). It was found that the blends which are stable at room temperature were also stable at the temperature range of 35 to 45^{0}C. The substitute fuels prepared using 190^0 proof ethanol having 10, 15 and 20 % ethanol and 22, 26 to 29 % ethyl acetate were also found stable in selected temperature range of 35 to 45^{0}C. The substitute having 10, 25, 30 and 35 per cent ethanol of 190^0 proof were found unstable at room temperature. The substitute having 10, 15 and 20 percent of 180^0 proof ethanol were stable at the selected temperature range. However, the substitute having 25 and 30 per cent of 180^{0}proof ethanol were unstable at room temperature. Out of the four substitutes prepared using 170^0 proof ethanol only two having 10, 15 and 20 per cent ethanol were found stable in the temperature range of room and the other having 25 per cent ethanol were unstable at room temperature. The observation on stability at different temperature range indicates that in the low temperature range of 35^{0}C, the stability of substitute having anhydrous ethanol was better than those having aqueous ethanol. It also evident from the table that substitute having aqueous ethanol were stable in low temperature range that substitute having aqueous ethanol were stable in low room temperature when 10 to 15 per cent aqueous ethanol was there in the substitute fuel. It is also evident that in order to have stable substitute fuel with aqueous ethanol, a very large preparation of ethyl acetate needs to be mixed in the substitute fuel. It was observed that ethanol proof significantly affected the requirement of ethyl acetate for preparation of stable fuels. It was concluded from the data that with an increase in ethanol content in a prepared substitute fuel, the requirement of ethyl acetate also increased. The aqueous ethanol required a large quantity of ethyl acetate to form stable micro emulsion with biodiesel whereas anhydrous ethanol required lesser quantity of ethyl acetate to form the same.

4.2. Fuel Properties of Selected Blends

The substitute found stable at room temperature and having 10, 15 and 20 percent ethanol were selected to study their characteristics fuel properties. The properties of biodiesel and ethanol of 200^0, 190^0, 180^0 and 170^0 proof were determined.

The relative density of biodiesel was determined to be 0.8888 against the relative density of diesel as reported by Goering et al. (1983) as 0.840. The relative density of ethyl acetate surfactant was found to be 0.9062. The relative densities of 200^o, 190^0, 180^0 and 170^0 proofs ethanol were determined as 0.7923, 0.8113, 0.8265 and 0.8416 respectively.

The kinematic viscosity of biodiesel was found to be 33.4 MPa.s whereas the kinematic viscosity of biodiesel fuel was found ranging between 30.5 to 44.5MPa.s at 38^{0}C temperature. The kinematic viscosity of ethyl acetate was found as 24.9 MPa.s and those of 200^0 and 190^0 proof ethanol were found as 12.7, 11.0, 11.3, 06.6, 06.3 and 0.60, respectively at the same temperature. The kinematic viscosities of six substitute fuels 200^0-10/0/90, 200^0-15/5/80, 200^0-20/10/70, 190^0-10/22/68, 190^0-15/26/59 and 190^0-20/29/51 were found to be 12.7, 11.0, 11.3, 6.6, 6.3 and 6.0 MPa.s, respectively. The kinematic viscosity of substitute was found to be 10 to 22 per cent lesser than that of the biodiesel.

The flash point and fire point of biodiesel fuel was found as 60^{0}C and 67.7^{0}C, respectively. The flash point of 200^0, 190^0, 180^0 and 170^0 proof ethanol was found as 16.7, 18.2, 20.2 and 20.8^{0}C respectively. The fire point of above proofs of ethanol was found as 21.5, 23.8, 25.3 and 26.7^{0}C respectively. The flash points of twelve substitutes 200^0-10/0/90, 200^0-15/9/76, 200^0-20/10/70 and 190^0-10/22/68, 190^0-15/26/59, 190^0-20/29/51 was found as 38.0, 25.4, 22.5, 19.6, 17.5 and 15.2^{0}C respectively. The fire points of above prepared substitute fuels were found as 43.5, 30.8, 27.3, 24.9, 22.8 and 20.4^{0}C, respectively. The drop in flash and fire point of substitute was due low flash and fire point of the ethyl acetate the reduce flash and fire point of substitute reflects that the grater care in handling this substitute fuels may be required during high ambient temperature conductions.

4.3. Performance Results of the Test Engine

It was found that the engine developed 3.669 kW brake power at 1500 rpm with diesel fuel. The engine developed 3.674, 3.684 and 3.676 kW brake power at the full load conditions with 200^0-10/0/90, 200^0-15/5/80 and 200^0-20/10/70 prepared substitute fuels, respectively. The observed engine speed at above brake power was 1502, 1506 and 1503 rpm respectively. The engine speed at full load was found higher on brake power on substitute fuel as biodiesel and this way have resulted in slightly higher brake power on substitute at full load.

During experiment it was observed that fuel consumption of the engine gradually increased with increases in brake load was found maximum at 100 per cent brake load on all fuel types. The fuel consumption of the engine at full load conditions when the engine developed its rated power was 1.837, 2.037, 2.002 and 2.071 l/h diesel and on 200^0-10/0/90, 200^0-15/5/80 and 200^0-20/10/70 substitute fuel, respectively. Was also observed that the fuel consumption of the engine on diesel was lowest at full the brake load conditions compared to the three substitute fuel tested. This may be due to reason that the heat values of substitute fuels. It has been also observed that fuel consumption on 200^0-20/10/70 substitute fuel was very high compared to diesel and other substitute fuel between no loads to 100 percent load.

The brake specific fuel consumption (BSFC) of the engine on diesel at full load (100 per cent) was found as 314 g/kW –h and 200^0-10/0/90, 200^0-15/5/80 and 200^0-20/10/70 ethanol –ethyl acetate –biodiesel substitute fuel was found as 365, 357 and 369 g/kW- h, respectively. The BSFC of the engine gradually decreased with increases in brake load due to fact the brake power of the engine increased the with brake load further. It was observed that BSFC of the engine was maximum at 20 per cent brake load. At 20 per cent brake load the BSFC of the engine was 595 g/kW- h on diesel and on 200^0-10/0/90, 200^0-15/5/80 and 200^0-20/10/70 substitute fuel was 758, 696 and 922 g/kW-h respectively. The highest BSFC of the engine was found as 922 g/kW-h on 200^0-20/10/70 substitute fuel at brake load of 20 per cent. The drop in brake specific fuel consumption of the engine was at a higher rate unto 60 per cent brake load. The change in the BSFC of the engine 60 to 100 per cent brake load was less. This is due to the reason that increase in brake power of the engine from 60 to 100 per cent brake load was less as compared to increase in brake power between no load to 60 per cent brake load. It is evident from the figure that the BSFC of the engine at all brake loads was considerably higher on 200^0-20/10/70 substitute fuel (922 g/kW-h at 20 percent load to 369 g/kW-h at 100 percent load) compared to other substitute fuel.

It was observed that the emission of CO_2 from the exhaust of the engine on diesel was found to vary from 0 to 2 % between no loads to 100 % brake load. It was also observed that the emission of CO_2 on diesel remained constant 0 percent 100 percent brake load. The emission of CO_2 from the exhaust of the engine when operating on 200^0-10/0/90, 200^0-15/5/80 and 200^0-20/10/70 substitute fuels ranged between 1 to 2.0, 1 to 5.5, 1 to 4 and 1.1 to 4.1 % respectively. The emission of CO_2 from the exhaust of the engine was found highest as 5.5 per cent on 200^0 -10/0/90 substitute fuel. It was also observed that the emission of CO_2 was more aqueous substitute fuel.

The emission of nitrogen dioxide from exhaust of the engine on diesel was found to be in the range of 158 to 618 ppm between no load to 100 per cent brake load the level of NO_2 emission from the engine on 200^0-10/0/90, 200^0-15/5/80 and 200^0-20/10/70 substitute fuel was found to vary from 72 to 613, 136 to 625 and 153 to 607 ppm respectively. Between no load to 100 per cent brake loads. The emission of NO_2 from the engine was found lower on substitute fuel prepared using anhydrous and aqueous ethanol than the diesel fuel under no load at full load. This indicates that with increase in preparation of ethanol and ethyl acetate in substitute fuel the emissions of NO_2 have reduced.

The emission of NO from the engine on diesel was found to very in the range of 158 to 989 ppm between no load 100 per cent brake load. The level of NO emission from the engine running on 200^0-10/0/90, 200^0-10/0/90 and 200^0-10/0/90 substitute fuel was found to very in the range of 63 to 681, 115 to 625 and 133 to 607 ppm respectively between no loads to 100 per cent brake load. The emission of NO from the exhaust of the engine was found lower on substitute fuel than the diesel fuel between all brake loads. The emission of NO from the engine running on substitute fuel of 200^0 proof ethanol was higher in almost all brake load conditions. Further, the lowest emission at brake load condition was observed using 200^0-20/10/70 substitute fuel which indicates that presence in ethanol and proportion of ethyl acetate has reduced the emission of NO.

5. Conclusions

Based upon the study, the following conclusions were drawn:

5.1. The feasibility of preparation of ethanol-ethyl acetate –biodiesel substitute fuel depends on phase separation characteristics of ethanol from biodiesel. The phase separation characteristics of ethanol –biodiesel are affected by the proof level of ethanol as well as the amount of surfactant required for blending.

5.2. The requirement of ethyl acetate as surfactant to prepare stable and homogeneous substitute fuel was observed to be very high with aqueous ethanol. The requirement of ethyl acetate was found to increase with decrease in proof level of ethanol.

5.3. The relative density of ethanol –ethyl acetate –biodiesel substitute fuel was found to increase with decrease in proof of ethanol and increases in level of ethyl acetate in the substitute fuel.

5.4. The kinematic viscosity of ethanol- ethyl acetate-biodiesel substitute fuel was found to decrease with increase in level of ethanol and ethyl acetate in the substitute fuel. However, the kinematic viscosity of different proofs of ethanol was found to increase with decrease in proof level of ethanol.

5.5. The flash and fire point of different proof of ethanol was found to increase with decrease in proof level of ethanol and that of substitute fuel was found to decrease with increase in level of ethyl acetate in the substitute fuel.

5.6. The compatibility of substitute on the basic of fuel properties suggested that ethanol of 200^0 proof may be used for preparation of ethanol- biodiesel substitute fuel using ethyl acetate as surfactant.

5.7. The brake power of the engine was found to increases with increases in brake load under all fuel types tested. The engine was found to develop its rated power of 3.669 kW at the engine speed of 1500 rpm at full load on diesel. The substitute fuel of ethyl acetate-biodiesel was found to be having similar power producing capabilities as biodiesel under each load conditions. The fuel consumption of the engine on all load types tested was found to increases with increase in brake load. The fuel consumption of the engine on all fuel types was found to be maximum at 100 percent brake load.

5.8. The brake specific fuel consumption (BSFC) of the engine was found to decrease with increase in brake load and was found maximum at 20 percent brake load on all fuel types tested. This BSFC of the engine on diesel200^0-10/0/90, 200^0-15/9/76, and 200^0-20/10/70 substitute fuel at full load were found to be 314, 365, 357 and 369 g/kW –h respectively.

5.9. The emission of carbon dioxide from the exhaust of engine was found to decrease with increase in brake load.

5.10. The emission of nitrogen dioxide was found to decrease to increases in brake load under all types tested and was found to be brake load.

5.11. The emission of nitric oxide (NO) was found to increase with increase in brake load under all fuel types tested and it decreased on substitute fuel.

6. References

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