Stability Analysis of Biodiesel, Ethanol and Diesel Blends and Performance Testing of CI Engine with These Stable Blends

Vicky Singha[1], S. Rajesh[2]

[1] Department of Mechanical engineering Bapuji Institute of Engineering And Technology.
[2] Department of Mechanical engineering Bapuji Institute of Engineering And Technology.
Davangere

Abstract- **The work is carried out to determine the feasibility of extents of using the ternary mixtures of ethanol-biodiesel-diesel(EBD) with maximum reduction of the fossil fuel(diesel) without sacrificing much of the advantages of unblended fossil fuel. Experiments are done to list off the beneficial properties that can be expected in blending the three fuels(EBD) keeping the biodiesel parameter constant at 50% and varying other components.The physical properties like Viscosity, density, Calorific Value, Flash Point, Fire Point, Cloud, Point, Pour Point are determined so as to compare with the diesel. The engine performance such as brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), mechanical efficiency (ME), etc. of the blends are tested with the increase in ethanol content in the blended fuel at overall operating conditions .The emissions such as CO, HC,NO_x, etc.are tested for detecting the influence of increasing ethanol andits suitability to the environmental standards without any modifications in the existing Compression ignition engines.**

Keywords: Biodiesel, Acid oil, diesohol, Blending, Homogeneity, performance, emissions.

I. INTRODUCTION

Biodiesel and alcohols are source of clean renewable fuels and have received considerable attention in recent years as alternative fuels in diesel engines. Alcohols and diesel mixes homogeneously only upto a limited extent over a wide range of temperatures due to the difference in their chemical structures. Among the various alcohols, ethanol is the mostly preferred fuel as it is renewable and produced from various agricultural feed stocks and bio-ethanols gained much attention in recent years.Several techniques are adopted to utilize ethanol in the diesel engines such as blending ethanol with diesel(duel fuel mode), spark assisted ignition system, use of ignition improvers, etc. Nevertheless, most of the techniques require engine modification or the use of expensive additives for making compatible with compression ignition engines.

The phase stability revealed that the diesel blends is not stable and separated after 2, 5, 24 and 80 hours, for 20%, 15%, 10% and 5% ethanol concentration, respectively. Whereas for EBD blends, the separation time is longer than that of the first system and reached 1, 3 and 9 days for 20%, 15%, 10% ethanol concentration, respectively[1]. The blending of diesohols with biodiesel is an ideal choice to use ethanol in diesel engines as they do not require any engine modification. But the major challenge in using blends is the phase separation.

In this work, biodiesel (from waste Acid oil from oil refineries) produced through transesterification is used as a bridging agent between ethanol and diesel to prevent phase separation. Biodiesel has been used both as an alternative fuel as well as an additive for diesohol .This homogeneity is due to the fact that the biodiesel can act as an amphiphile and form micelles which have polar heads and non polar tails. These molecules are attracted to liquid interfacial films and to each other. These micelles acts as non-polar or polar solutes, depending on the orientation of the biodiesel molecules. When the diesel fuel is in the continuous phase, the polar head in a biodiesel molecule orients itself to the ethanol, and the non-polar tail orients to the diesel [2].

II. METHODOLOGY

Samples of waste acid oil from oil refineries are collected and tested for their free fatty acid contentFFA test was verified by titration done by taking 50ml of isopropyl alcohol in a clean & dry 250 ml conical flask., few drops of N/10 NaOH (0.1 Normality) solution is added to flask and shaken well. 10 grams of sample oil is add it to the conical flask and then the mixture is heated and allowed to cool and hence a few drops of phenolphthalein indicator is added into the conical flask and titrated against prepared NaOH solution. Best among those sample showed FFA reading of 8.2% and transesterification is carried out to extract Bio-dieselfrom the waste acid oil.

Blends are prepared by taking proportionate biodiesel(produced from waste acid oil), diesel from nearby IOC retail outlet and ethanol (99.5% purity) from distilleries.

Five blends of B50D(50% Biodiesel and 50% diesel), E04B50D(ethanol 4%, biodiesel 50% and diesel 46%), E08B50D(ethanol 8%, biodiesel 50% and diesel 42%), E12B50D(ethanol 12%, biodiesel 50% and diesel 38%), E16B50D(ethanol 16%, biodiesel 50% and diesel 36%) are prepared proportionately for the work. Ethanol percentage was restricted upto 16% range because of its unstable behavior in the engine while using more than 20% in EBD blends such as more engine vibrations.

Figure 1: Image shows 100ml blend samples

At first 100ml of blends are prepared for their basic physical properties for comparing their homogeneity and feasibility with the fuel standards for engine studies. Figure 1 shows the prepared 100ml blends and no phase separation was monitored even after 48 hours of observation.

III. EXPERIMENTAL SETUP

A Kirloskar 5.2KW 4Stroke Single Cylinder Water Cooled is operated with the fuel blends to check their engine performances. AVL DIGAS 444 D gas analyzer is used to measure HC , CO and NOX emissions, a non-dispersive infrared measurement for HC, CO emissions.

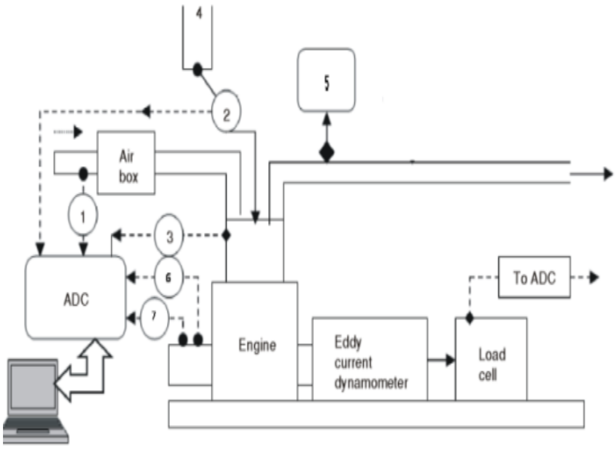


Figure 2: Image shows the engine Experimental set up

In figure 2, 1 implies the air flow sensor, 2 – fuel flow sensor, 3 – pressure sensor, 4 – diesel tank, 5 – five gas analyzer, 6 – speed sensor, 7 – crank angle

PARTICULARS	SPECIFICATION
Company	Kirloskar
Type	4Stroke Single Cylinder
Power	5.2KW
Bore	87.5mm
Stroke	110mm
Cooling	Water Cooled
Speed	1500rpm
Compression ratio	17.5
Fuel injection	Mechanical Injection

Table 1: Table shows the test Engine Specifications

IV. EXPERIMENTAL RESULTS

A. Physical properties of the blends

Fuel	Density (kg/m^3)	Viscosity (Cst) @40 Ċ	Calorific Value (MJ/Kg)	Flash Point (Ċ)	Fire Point (Ċ)	Cloud Point (Ċ)	Pour Point (Ċ)
Ethanol	801	1.23	28.62	18	32	-3	<-35
Diesel	845	3.45	44.43	52	63	-5	-16
Biodiesel	890	5.82	39.47	113	119	3	-1

Table 2: Tables shows the base fuel properties

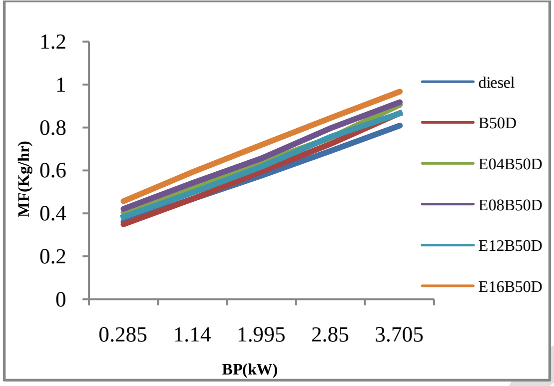
Fuel	Density (kg/m^3)	Viscosity (Cst)@40Ċ	Calorific Value (MJ/Kg)	Flash Point (Ċ)	Fire Point (Ċ)	Cloud Point (Ċ)	Pour Point (Ċ)
B50D	838.5	4.3758	42.169	90	97	-1	-3
E04B50D	836.7	4.2729	41.313	79	86	-2	-4.5
E08B50D	836.44	4.1041	40.152	71	77	-2	-4.5
E12B50D	835.56	3.9286	39.793	62	68	-2	-5
E16B50D	834.23	3.5429	39.570	53	59	-2	-5

Table 3: Tables shows the blended fuel properties

According to the experimental results the calorific value is found to be decreased with the increase in the ethanol content. Both the kinematic viscosity and density decreased with the increase in the ethanol content for the fuel blended with 50% biodiesel as constant parameter in the blends as seen in the table below and satisfies ASTM standards. Biodiesel effectively increases the viscosity and density but ethanol compensates the properties to comply with the standards similar to diesel. Likewise, pour point is further decreased thus increasing the low temperature performance of the blended fuel by 3Ċ as compared to that of dual fuel (B50D).

B. Engine results

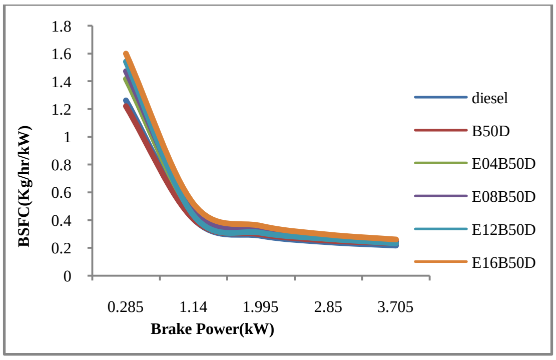
1. Brake power V/s mass of fuel consumption(MF)



Graph 1: Graph shows the comparision between Brake power and Mass of fuel consumption

Graph 1shows the variation of mass of fuel consumption with respect to load. As the brake power increases, mass of fuel consumption also increase.Mass of fuel consumption for biodiesel and its blends is less than the diesel and increases with the increase in ethanol in the blends. This may be due to lower heating value of the blends and thus more fuel is required to generate the same power as that of diesel.

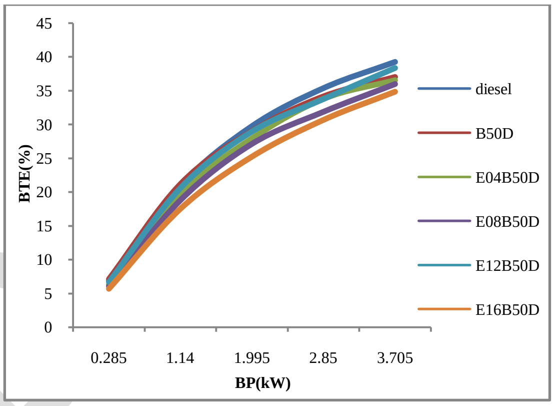
2. Brake power vs Brake specific fuel consumption(BSFC)



Graph 2:Graph shows the comparision between Brake power *and* Brake specific fuel consumption

The Graph 2 shows the variation of BSFC with respect to brake power. Brake specific fuel consumptions descend from lower to higher brake power. At higher brake power conditions the brake specific fuel consumption decreases. Graph shows the variation of brake specific fuel consumption (BSFC) with brake power for Diesel, Biodiesel, ethanol blends. As the brake power increases, BSFC decreases for both diesel and biodiesel blends. These behaviours are reasonable because the oxygenated blends have low calorific value compared to that of diesel fuel. The improvement in energy consumption is due to better combustion on account of oxygen enrichment. The BSFC in case of blends were higher compared to diesel in the entire load range due to its lower heating value.

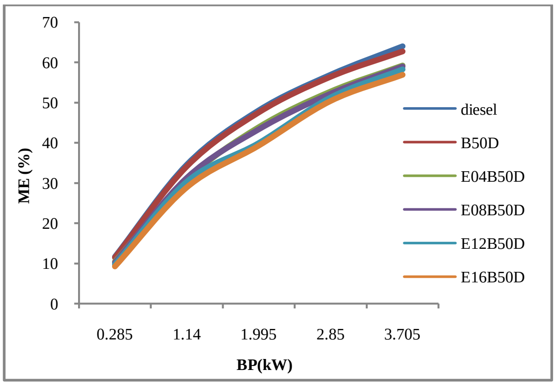
3. Brake power vs Brake Thermal Efficiency



Graph 3:Graph shows the comparisionbetween Brake power and Brake Thermal Efficiency

From the graph, it is clear that the brake thermal efficiency of the blends arecloser to diesel. At higher brake power, the efficiency is marginally higher for other biodiesel blends. With increasing BP the exhaust gas temperature is not so high for the EBD blends. It results in smaller peak heat release rate and increase effective pressure to do work. Consequently the work output is high and therefore the Brake thermal efficiency increases.

4. Brake power V/s Mechanical Efficiency(ME)

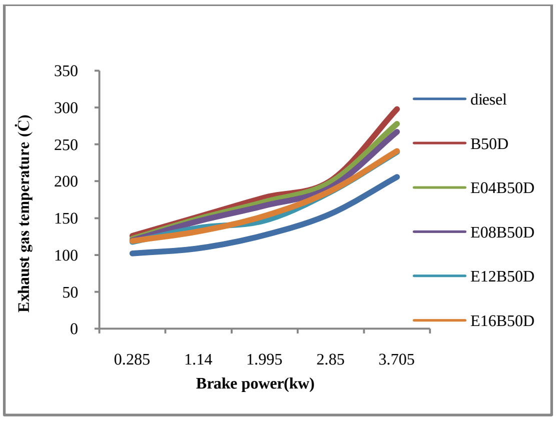


Graph 4: Graph shows the comparisionbetween Brake power and Mechanical Efficiency

Mechanical efficiency is defined as the ratio of brake power (delivered power) to the indicated power (power provided to the piston). From the graph 4 it is the evident that mechanical efficiency increases with increasing load.

Mechanical efficiency of EBD blends are lower than that of the diesel, as the percentage of diesel in blends decreases, the efficiency also tends to decrease. This may be an due to the lower heating values of the bio diesel and ethanol than the diesel for which the B50D has greater efficiency than EBD blends as ethanol further lowers its intrinsic heating value.

5. Brake power vs Exhaust gas temperature(EGT)



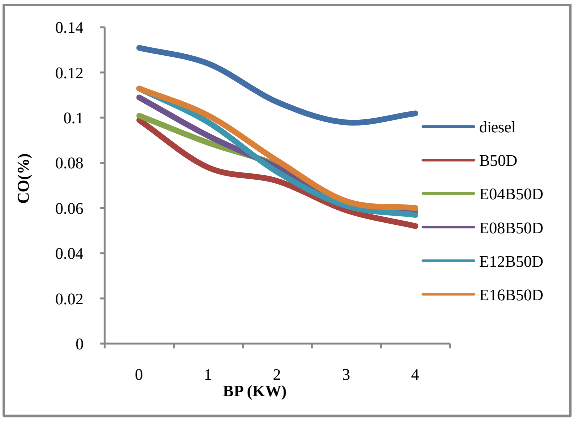
Graph 5:Graph shows the comparisionbetween Brake power and exhaust gas temperature

From the graph 5 it is evident that the exhaust gas temperature of the blends are higher than the diesel due to their high calorific values. Out of which B50D has the highest EGT as compared to other. EBD blends showed lower EGT may be due to the cooling effect of the alcohols, out of which E12B50D showed much lower EGT at mid loading conditions.

The temperature generated during combustion process is directly related to the NOx emission so it can be estimated that the addition of ethanol to the blends may result in the lower NOx emissions. Here E16B50D showed least EGT but E12B50D compensated in the mid load conditions.

C. Emission characteristic

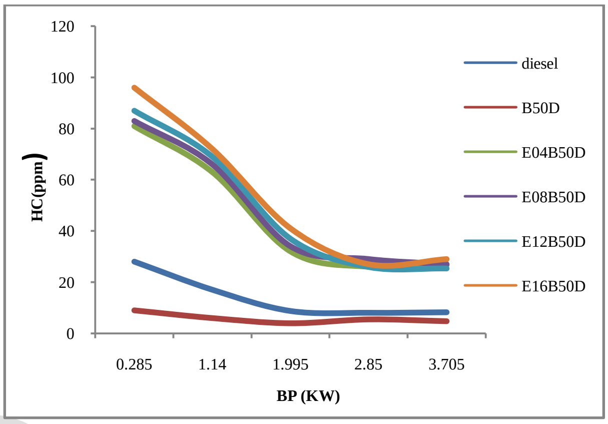
1. Carbon Monoxide V/s Brake power



Graph 6: Graph shows the Variations of Carbon Monoxide with Brake power at 210 bar.

Graph 6 shows the CO emissions as a function of load for standard diesel and the other four blends. It is clearly seen from the figure that CO emissions increase by increasing ethanol concentrations. This is perhaps due to lower cetane numbers of alcohol fuels, which increase the ignition delay, leading to incomplete combustion, which increases CO emission.

2. Unburnt Hydrocarbon V/s Brake power

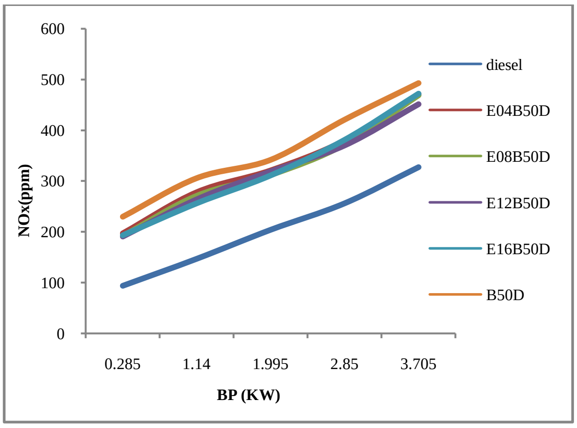


Graph 7: Graph shows the Variations of unburnt hydrocarbon with Brake power at 210 bar.

The variation in HC emissions with Brake Power is shown in graph 7. It is observed that the HC for only B50D , emission decreases with increase in load and is rather even less than the diesel. As the Catane number biodiesel is higher than diesel, it exhibits a shorter delay period and results in better combustion leading to low HC emission. Also the intrinsic oxygen contained by the biodiesel was responsible for the reduction in HC emission.

This graph also indicates that increasing ethanol concentration in EBD blends, increases HC emissions. HC emission is a product of incomplete combustion. The results show that ethanol concentration of 12% have the positive effect of higher oxygen content rather than the cooling effect of ethanol for which the HC emission is observed to be reduce for E12B50D blends at higher loads.

3. Oxide of Nitrogen V/s Brake power



Graph 8: Graph shows the Variations of oxide of Nitrogen with Brake power at 1500rpm.

From Graph 8, it is observed that, NOx emissions are reduced by increasing ethanol concentrations in biodiesel ethanol diesel blends. It is seen that ethanol-blended fuels of E12B50D shows lower emissions as compared to other blends , which might be due to that a low concentration of ethanol, increases the oxygen content of the fuel mixture, which leads to better combustion and a higher combustion temperature whereas the higher concentration initiates the cooling effect of ethanol, leading to a lower combustion temperature and a reduction of NOx emission but higher concentration .

V. CONCLUSIONS

The objective of the work was to monitor the basic behaviour of the fuel properties that are affected by the blending of the ethanol, biodiesel and diesel in order to reduce the usage of the fossil diesel as least as possible utilizing the renewable resources. According to the experimental results, the calorific value is found to be decreased with the increase in the ethanol content. Both the kinematic viscosity and density decreased with the increase in the ethanol content for the fuel blended with 50% biodiesel as constant parameter in the blends but satisfies ASTM standards as the biodiesel contents compensates the effects of ethanol. Likewise, pour point is further decreased thus increasing the low temperature performance of the blended fuel by 3Ċ as compared to that of dual fuel (B50D).

Hence, the property based preferences for the low temperature regions, the ternary blends of ethanol, biodiesel and diesel are preferred more as compared with that of binary mixtures.

The following conclusions have been made in this study with reference to the engine performances and emissions :

1. BSFC of 5KW diesel engine when operated with EBD blends as compared with Diesel at different engine loads were found to increase by 3.49% to 6.72% for the mid load conditions whereas BTE was found to decrease by 2.47% to 5.32% with B50D concentration in the fuel blends for the same. Whereas among the blends tested, E12B50D showed optimum results at higher loading conditions.

2. Mechanical efficiency of EBD blends are reduced when compared to the dual fuel B50D blends but compensated by the E08B50D and E12B50D blends at higher load conditions.

3. Exhaust gas temperature of E12B50D is optimum at mid loads when compared to other blends and thus can be preferred for lower NOx emissions.

4. The CO and HC emissions of the diesel engine when operated with EBD blends as compared with diesel, B50D blends shows lower HC emission than both diesel and other EBD blends. For CO emissions E50D is 12% TO 16% lower than EBD blends and 26% to 34% less than diesel but E12B50D shows optimum results at higher loads.

5. NOx emissions were found to be higher with the dual fuel(biodiesel-diesel) B50D blend when compared to the other ethanol blended fuels by 12% to 14% but both has higher Nox values as compared to the diesel. The E12B50D blend has the lowest Nox emission values among all the blendsat higher engine load conditions.

From the results obtained with respect to the above observations, the blend E12B50D can be suggested to be the optimum choice for using in CI engine as an alternate fuel as it has shown comparatively lower BSFC , higher BTE, lower exhaust gas temperature and lower emission characteristics among all the blends in same working conditions without any modifications in the existing CI engines.

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REFERENCES

[1] M. Al-Hassan, H. Mujafet , M. Al-Shannag . “An Experimental Study on the Solubility of a Diesel-Ethanol Blend and on the Performance of a Diesel Engine Fueled with Diesel-Biodiesel - Ethanol Blends “. Volume 6, Number 2, April 2012 , ISSN 1995-6665 Pages 147 – 153.

[2] S.A. Shahir n, H.H. Masjuki, M.A. Kalam, A. Imran, I.M. Rizwanul Fattah, A. Sanjid. “Feasibility of diesel–biodiesel–ethanol/bioethanol blend as existing CI engine fuel: An assessment of properties, material compatibility, safety and combustion”. Renewable and Sustainable Energy Reviews 32 (2014) 379–395.

[3] Xiaoyan Shia, XiaobingPanga, YujingMua, Hong Hea, ShijinShuaib, JianxinWangb, Hu Chenb, Rulong Lib,” Emission reduction potential of using ethanol–biodiesel–diesel fuel blend on a heavy-duty diesel engine”. Atmospheric Environment 40 (2006) 2567–2574.

[4] D.C Rakopoulos, "Effect of ethanol–diesel fuel blends on the engine performance and emissions of heavy duty DI diesel engine". Energy Conversion and Management, Vol. 49, No. 11, 2008, 3155–62.