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Research Article

An Experimental Study of Diesel Engine Characteristics Fueled with Ethanol Blended Diesel

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Abstract

In the present study an experimental investigation was conducted with Ethanol as an alternative fuel for the diesel engines. To investigate the engine characteristics using ethanol- diesel blended fuel a four stroke, single cylinder DI-CI engine was used. The engine was tested at different loading conditions with ethanol-butanol-diesel percentage by volume ratios of 10:5:85(E10B5D85), 15:5:80(E15B5D80) and 20:5:75(E20B5D75). To form stable mixture of ethanol and diesel a 5% butanol was used in all blends. The test results show that it is feasible to use ethanol blended diesel with butanol to replace pure diesel as the fuel for diesel engine. The brake thermal efficiencies were comparable with that of the diesel for the test engine when fuelled by the ethanol blended diesel. Increase of brake specific fuel consumptions which is due to the lower heating value of ethanol were observed with blends. The emissions characteristics were also studied when fuelled by the blends, it is observed that the carbon monoxide (CO) and hydro carbon (HC) were reduced when the engine ran at all loads. The nitrogen oxides (NO_X) emissions were increased for all blends at all loads.

Keywords: *Diesel Engine, ethanol, performance, emission*

1. Introduction

One day, our sources for traditional fuels including petroleum would be depleted. Owing to the fact that these fuels are typically not renewable, a lot of people are worried that a day would come when the demand for these fuels would be more than the supply, triggering a considerable world crisis. Non-environmentalists also concur with the opinion that the majority of oil fields (situated in the Middle East) in the world are associated with problems – both political and economic.

Many countries in the world are also facing lot of issues regarding environmental impact and availability of fossil fuels. Non renewability, rapid depletion and limited in reserves are the main challenges of existing fossil fuels. The use of these conventional fuels mainly in transportation sector has led adverse effect on environmental pollution (Demirbas A *et al*, 2011). So researchers are directed to search for clean alternative fuels such as alcohols, vegetable oils and biodiesel (Dogan O, 2011, Demirbas A, 2008 and Chen Z *et al*, 2014). It is an inevitable for the development and utilization of alternative energy. Alcohol is considered as one of the suitable fuel substitution for diesel engines because it allows the diesel fuel to burn completely due to presence of more oxygen which improves engine characteristics (Surisetty VR *et al*, 2011). Methanol, ethanol and butanol (Masum BM *et al*, 2014, Uyumaz A, 2015 and Al-Hasan M, 2003) are the alcohols which attract the attention of most of the researchers recently because of their ease of availability. More works were carried out with methanol from the past few years and less attention was paid towards ethanol and butanol. Ethanol and butanol can be produced from various renewable resources such as corn, sugarcane and wheat etc. (Qureshi N *et al*, 2013 and Pfromm PH *et al*, 2010). Because of their high octane number, they are considered primarily good fuels for spark ignition engines. They have also been considered suitable fuels for compression ignition engines, mainly in the form of blends with diesel fuels (Hansen AC *et al*, 2005).

(S. Gomasta and S.K. Mahla, 2012) investigated the effect of ethanol blended diesel on engine performance and emissions of a diesel engine. The effect of ethanol addition on engine performance was evaluated using single cylinder, four stroke and direct injection diesel engine. The acquired data were analysed for various parameters such as break thermal efficiency, break specific fuel consumption, break specific energy consumption and exhaust gas temperature. Emission parameters CO, CO_2 and Unburned hydrocarbon are also tabulated. The performance parameters were marginally inferior but the emission is significantly reduced as the blend ratio is increased. (Hiregoudar

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Yerrennagoudaru *et.al*, 2014) studied the effect of ethanol blended jatropa oil on engine performance and emissions of a diesel engine. In their study, the diesel engine was tested using Bio fuel (90%Jatropa oil+10%Ethanol). Based on the performance and emissions of B10 fuel, it is concluded that the bio fuel oil represents a good alternative fuel with closer performance and better emission characteristics to that of a diesel.

(De-gang Li *et.al,* 2004) studied experimental results of ethanol blended diesel on engine performance and emissions. The experiments were conducted on a water-cooled single-cylinder Direct Injection (DI) diesel engine using 0% (neat diesel fuel), 5%, 10%, 15%, and 20% of ethanol in diesel blended fuels. The results indicate that the brake specific fuel consumption and brake thermal efficiency increased with an increase of ethanol contents in the blended fuel at overall operating conditions; smoke emissions decreased with ethanol–diesel blended fuel, especially 10% and 15% ethanol blend. CO and NO_x emissions reduced for ethanol–diesel blends, but THC increased significantly when compared to neat diesel fuel.

Hence in this current work the experimental investigation is carried out on DI-CI engine to evaluate performance and emission characteristics with ethanol blended diesel.

2. Materials and methods

2.1 Engine

The experimentation was carried out on **Kirloskar** 4-Stroke 1-Cylinder water cooled Variable Compression Ratio Diesel engine which is shown in figure 1.

Figure 1 Experimental engine set up

An Eddy Current Dynamometer is attached to it to vary the loads. Manometer and rotameter are provided to measure the air flow and water flow. The detailed technical specifications of the test engine are given below table 3.

Table 1 Stratification Time for Blends without butanol additive

Fuel Blend	E10 D90	E15 D85	E20 D80
Time for Stratification	96 hours	50 hours	28 hours

Table 2 Stratification Time for Blends with butanol additive

Fuel Blend	E10B5D85	E15B5D80	E20B5D75
Time for Stratification	120 days	90 days	60 days

Table: 3 Properties of Fuels

Properties	Diesel	Ethanol	n-Butanol	E10B5D85	E15B5D80	E20B5D75
Density (kg/m^3)	820	785	800	812	810	807
Viscosity (cSt)	3.20	1.2	2.86	3.07	2.78	2.55
Heat Content (MJ/kg)	42.5	26.4	33.2	40.425	39.62	38.56

Engine:	4 Stroke 1 Cylinder
Make:	Kirloskar
Rated speed:	1500
Fuel:	Diesel
Cooling:	Water Cooled
Bore:	87.5 mm
Stroke Length:	110 mm
Method of Starting:	Manual Cranking
Method of Ignition:	Compression Ignition
Compression Ratio:	17.5:1

2.2 Fuel

In the present study ethanol blended diesel was used to evaluate the performance and emission characteristics of DI-CI engine. Different blends were prepared with ethanol-butanol-diesel percentage volume ratios of 10:5:85(E10B5D85), 15:5:80(E15B5D80) and 20:5:75(E20B5D75), for test the engine. A 5% butanol was used for all the blends to form a stable mixture of ethanol and diesel. The stratification time(time for separation) of all the blends without and with butanol additive are given in table 1 and table 2 respectively. The blend of E10B5D85 was of the best stability with very little and almost unseen stratification. The important properties of these fuel blends are given in table 3.

2.3 Exhaust Gas Analyser

Indus 5 gas analyser (model: PEA 205) manufactured by INDUS scientific pvt.ltd Bangalore shown in figure 2 is used to analyse the emissions. Carbon Monoxide, Carbon Dioxide, Hydro Carbons, Oxygen, Oxides of Nitrogen can be measured with this analyser. Non – Dispersive Infra – Red (NDIR) technique for Carbon Monoxide, Carbon Dioxide, Hydro Carbons and Electro Chemical sensors for Oxygen and Oxides of Nitrogen measurement were used. It has an accuracy of ±0.06% for Carbon Monoxide, ±0.5% for Carbon Dioxide, ±12ppm for Hydro Carbons, ±0.1% for Oxygen. It can measure within the range of 0 – 15% for Carbon Monoxide, 0 – 15000 ppm for Hydro Carbons, 0 – 25% for Oxygen, 0 – 20% for Carbon Dioxide, 0 – 5000 ppm for Oxides of Nitrogen.

Figure 2 Exhaust gas analyser

3. Results and discussion

DI-CI engine performance characteristics BSFC, BTE and emission characteristics CO, HC, NO_X were evaluated at different loading conditions (3, 6, 9, 12kg) with ethanol blended diesel with butanol additive (E10B5D85, E15B5D80 and E20B5D75) and results are discussed as follows.

3.1 Brake Specific Fuel Consumption(BSFC)

The BSFC variation of various fuel blends with engine load is described is figure 3.

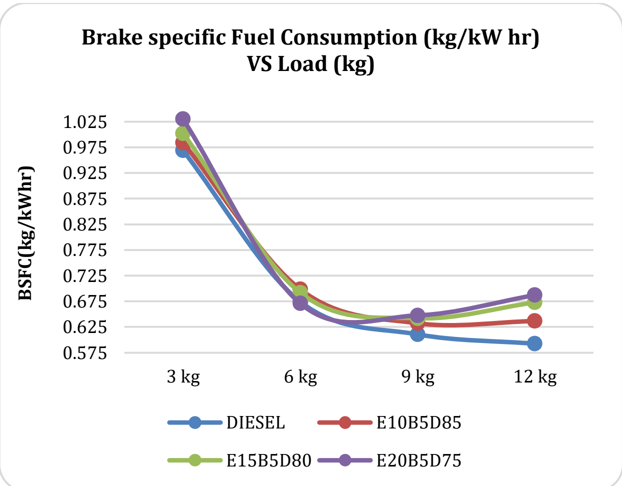

Figure 3 Variation of Brake Specific Fuel Consumption with Load

It is observed that BSFC was decreased with engine load for all the fuel blends. Higher BSFC values were observed with ethanol blends compared to pure diesel at all the load conditions. Increase of ethanol quantity in the blend increases the BSFC. This is due to lower heat content of ethanol compared to diesel. Among all blends E10B5D85 shows lower BSFC at higher engine loads. At 12 kg engine load the BSFC of pure diesel, E10B5D85, E15B5D80 and E20B5D75 are measured as 0.5924, 0.6366, 0.6729 and 0.6871 kg/ kWhr respectively.

3.2 Brake Thermal Efficiency(BTE)

The effect of ethanol blended diesel on engine brake thermal efficiency is shown figure 4. BTE increase with engine load was observed for all the fuel blends. Lower BSFC at higher loads is the reason for higher BTE. All the fuel blends record lower BTE compared to pure diesel. Increase of percentage of ethanol in the blend decreases BTE for all loads. Higher calorific value of diesel fuel is the reason for higher BTE for diesel.

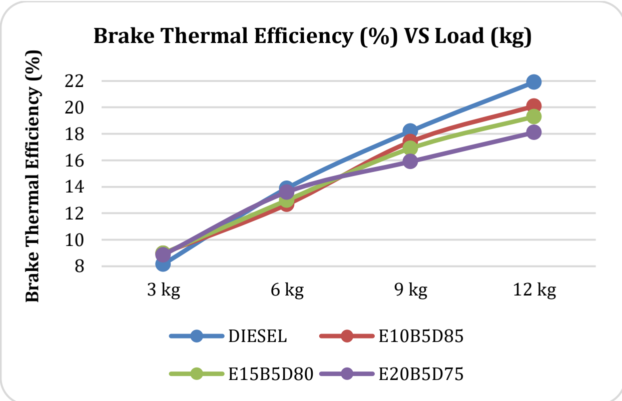

Figure 4 Variation of Brake Thermal Efficiency with Load

3.3 Carbon Monoxide(CO) Emission

The variation of CO emissions for all fuel blends with engine load is described in the figure 5.

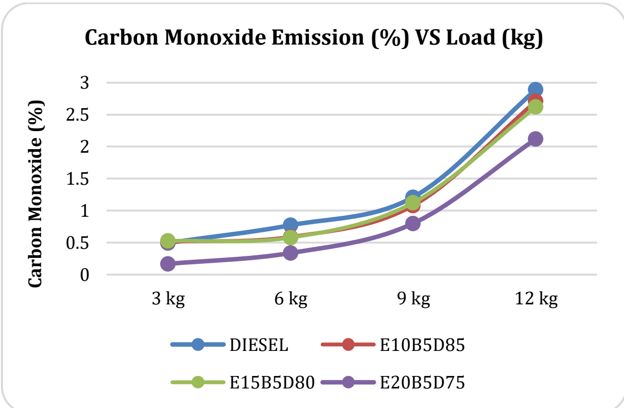

Figure 5 Variation of Carbon Monoxide Emission with Load

Increases of engine load increases CO emissions. Reduced CO emissions are obtained with ethanol blends compared to pure diesel at all loads. CO emissions decrease with increase of ethanol percentage in the blend. Comparatively the complete combustion of the oxygenated ethanol fuel is the reason for lower CO emissions with ethanol.

3.4 Hydro Carbons(HC) Emission

The variation of hydro carbon emission with engine load is shown in figure 6. From the figure it is observed that the HC emissions for all fuels increase with engine load. Lower HC emissions are observed from the engine when fuelled with ethanol blend compared to pure diesel. The more oxygen content ethanol promotes complete combustion is the reason for lower hydro carbon emission. At 12 kg engine load 35.17% less HC emissions are obtained with E20B5D75 fuel compared to pure diesel.

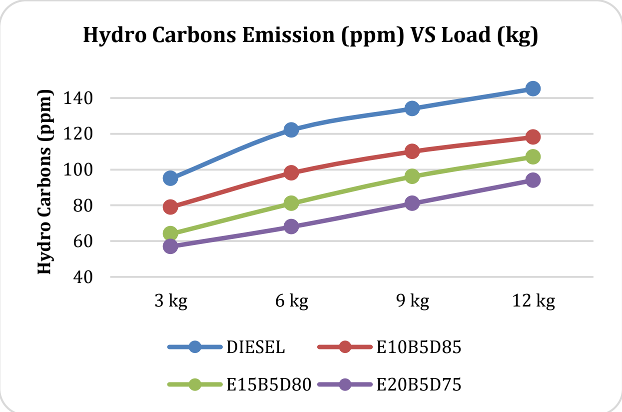

Figure 6 Variation of Hydro Carbons Emission with Load

3.5 Nitrogen Oxides(NO_X) Emission

Figure 7 shows NO_X emission variation with load for ethanol blends compared to pure diesel.

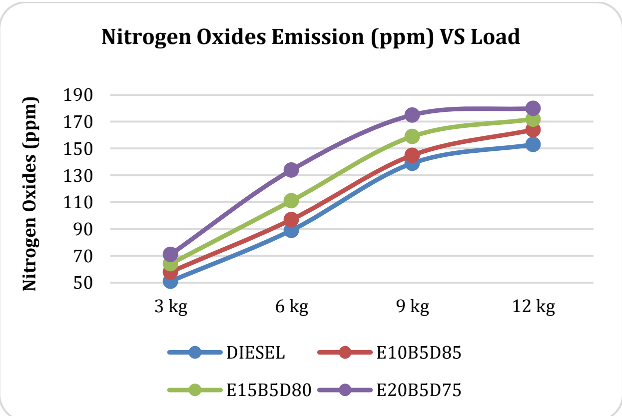

Figure 7 Variation of Nitrogen Oxides Emission with Load

Increase in NO_X emission is observed with engine load for all fuels. Higher NO_X emissions are observed for the blends than pure diesel at all load conditions. Because oxygenated ethanol fuel combustion produce higher NO_X emissions. The increased NO_X for ethanol blend is also due to early start of burning and increased premixed combustion.

Conclusion

An experimental investigation was conducted on the solubility and physical properties of the blends of ethanol with diesel and the effects of the application of these blends on the engine performance parameters and emissions. The tested blends were10%,15% and 20% of ethanol by volume and also with 5% of the additive of normal butanol. The engine was operated with each blend at different loads at engine speed of 1500 rpm. From the test results, the following conclusions are drawn.

Ethanol cannot be blended with diesel without the assistance of butanol additive. The blends of 10%, 15% and 20% ethanol (by volume) with diesel were all separated into two layers, when 5% butanol was added into the above blends, they all lasted longer and not less than 60 days without the phase separation.

The study showed that the butanol is a good additive for mixing diesel with ethanol, although the price of butanol was higher than that of diesel. It might not be economical to use butanol today but it would be in the future.

The fuel consumptions of the engine fuelled by the blends were higher compared with those fuelled by pure diesel. The more the ethanol was added, the higher fuel consumption was, because ethanol has low heating value so more fuel is needed when ethanol percentage increases.

The brake specific fuel consumption when fuelled by the blends was higher compared with pure diesel. The thermal efficiencies of the engine fuelled by the blends were comparable with those fuelled by pure diesel, with slightly higher efficiency at higher loads. E20B5D75 has better efficiency and nearer to diesel. CO and HC emissions were also very low at all loads for ethanol blends compared to pure diesel. 35.17% lesser HC emissions were observed with E20B5D75 at 12 kg engine load. NO_X emissions are slightly at higher side for all ethanol blends compared to diesel.

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