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Experimental Investigation of effect of n-butanol to Diesel on the Performance and Emission characteristics in Diesel engine

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Abstract : An Expermental investigation of diesel-butanol blends in various proportions is conducted in a diesel engine. Nitrogen oxides and smoke emission are the most significant emissions for the diesel engines. Especially, fuels containing high-levels oxygen content can have potential to reduce smoke emission significantly. The aim of the present study is to evaluate the influence of *n*-butanol/diesel fuel blends of higher *n*-butanol content (as an oxygenation additive for the diesel fuel) on engine performance and exhaust emissions in diesel engine. Blends take for this study are 30% and 45% of n-butanol along with diesel. Properties of the two blends are determined as per ASTM standards and tested in a diesel engine. The results are compared with diesel as base fuel. The results showed that for both blends there is a decrease NOx emissions for both blends at all loads compared to diesel and decrease of CO emissions at higher loads. However, there is a decrease of BTE and increase of BSFC, emissions of HC.
Keywords: n-butanol, diesel, performance characteristics, emission characteristics, diesel engine.

1. Introduction

World wide diesel engines are the main prime mover for the needs of transportation and stationary engines. Even though the emissions produced by the diesel engines are lesser than gasoline engines, the volume of diesel engines have the cumulative effect of total emissions and led to global warming and various health issues to mankind and plant life. Even though some gaseous fuels like CNG, LPG are replacing the consumption of diesel, they can only reduce the particulate emissions alone significantly [1-2] . Also the faster depletion of fossil fuels and increasing demand of the diesel engine usage triggered the necessity of alternate fuel to reduce the dependency on diesel alone.[3]. Biodiesels[18-31] and alcohols are the major two alternate liquid fuels for replacing or reducing the consumption of diesel. Blending of biodiesel more than 20% increases the NO_x emissions which may lead to environmental issues and depletion of vegetable oils.[4] Blending of alcohol has various limitations such as lower cetane number, lower viscosity, lower flash point. n-butanol is having closer properties as that of diesel and this can be blended with diesel to reduce the consumption of diesel in diesel engine [5]. Various researchers studied the performance, combustion and emission characteristics of diesel-n-butanol blends in diesel engine. Rakopolous et al.[6] studied the performance and emission characteristics of diesel-n-butanol blends and reported that there is a decrease of CO, NO_x emissions, smoke emissions and an increase of hydrocarbon (HC) emissions. Also it was reported that there is an increase of brake thermal efficiency (BTE) and an increase of brake specific fuel eonsumption (BSFC) for the blends. Lennox Siwale et al.[7] studied the performance and emissions characteristics of blend containing 20% n-butanol and reported that there was an increase of BTE and decrease of BSFC. Also it was reported that there was reduction in exhaust gas temperature. Byubgchul Choi et al. [8] studied the performance of diesel-n-butanol of 20% and reported that there was an increase in emissions of NO_x and decrease of BSFC. Also it was reported that the particle size distribution of the blend containing 20% n-butanol was less than 50 nm and an increase of polycyclic hydrocarbon. Merola et al. [9] studied the diesel-butanol blends in conventional and compared with optical diagnostics, reported that there was longer ignition delay and lesser NO_x emissions. Also it was reported that the emissions are smokeless. Sahin et al. [10] studied the micro blends of butanol from 2% to 6% with diesel and reported that there was an increase of NO_x emissions for the blend containing 6% n-butanol due to higher excess air coefficient and there was no significant improvement in heat release rate compared to diesel. Also, it was reported that there was an increase in BSFC of the fuel blends. Yu Liu et al. [11] studied the addition of butanol of 5% to diesel-biodiesel blends and reported that the addition of n-butanol reduces the soot formation in the blend and increases heat release rate due to more premixed zones. Zheng Chen et.al. [12] Studied the combustion and emission characteristics of n- butanol diesel blends up to 40% n-butanol and the results indicated that the ignition delay was higher than diesel and higher NO_x emissions as the temperature was higher. Yanchun Zhu et al [13] studied the performance of diesel engine with n-butanol in dual fuel mode and reported there was an increase in NO_x emissions, but with EGR, NO_x can be reduced. Also they indicated that no change in CO and HC emissions by EGR. Xiaobei cheng et.al [14] they found that soot emissions are reduced significantly for diesel-n-butanol blends and NO_x emissions are higher than diesel. Ming zheng et al. [15] observed the n-butanol-diesel blends in high compression ratio diesel engine and indicated that NO_x and soot emissions are lesser than diesel with minimum intake dilution (EGR) at low-mid loads. Also, BTE was higher at higher loads. Haozhong huang et.al [16], the effects of pre-injected timing and pre-injected mass of a diesel engine fuelled with diesel-n-butanol and reported that the addition of *n*-butanol consumed OH free radicals, which delayed the ignition time. With the increase of *n*-butanol, the BSFC and maximum rate of pressure rise increased, NO_x and soot decreased. Xiaolei Guet al. [17], studied the iso-butanol-diesel blends and the results showed that the ignition delay, peak cylinder pressure and heat release rate are higher than diesel. Also there was a decrease in soot emissions with little variation in the NO_x emissions. Also, there was a decrease in NO_x emissions and an increase in soot emissions at low EGR rate (less than 25%) without affecting fuel economy.

From the previous studies, it can be seen that the n-butanol-diesel blends in diesel engine has been tried up to 40% of n-butanol. The present study, 30% n-butanol and 45% n-butanol are blended with diesel and tested in a diesel engine for the performance, combustion and emissions characteristics and compared with diesel as base fuel. The results are presented.

2.1 Experimental setup

Kirloskar engine of 4.4 kW at 1500 rpm water cooled engine coupled to an eddy current dynamometer has been used for testing the blends. The engine used directly without any modifications in it. The experimental set up is shown in figure 1.and engine specifications is shown in Table1.

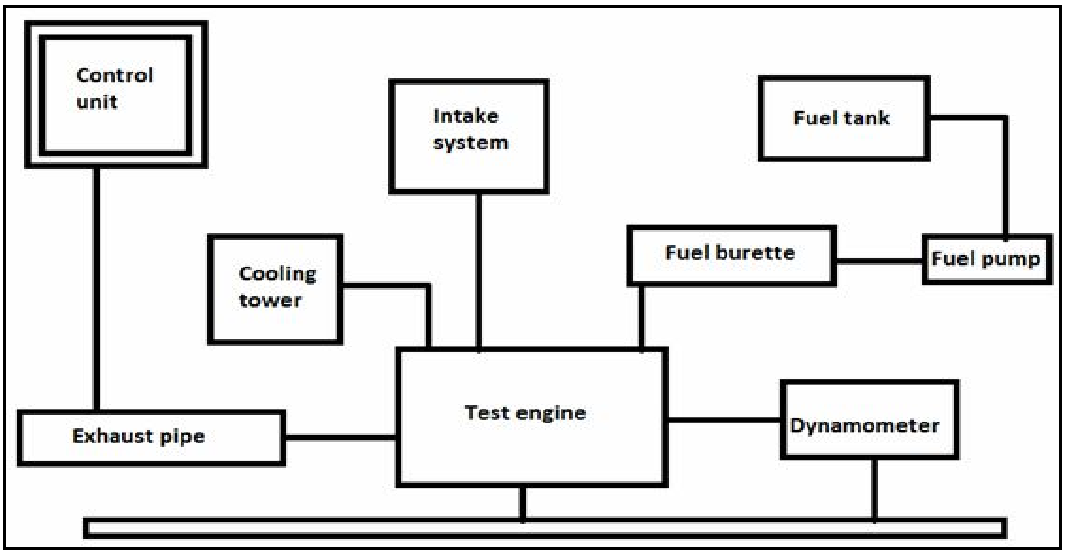

Figure 1.Test engine layout

Table 1. Engine specifications

Property	Description
Name	Kirlosker oil engine.
Type	Vertical 4 stroke, single acting ,totally enclosed, high speed compression ignition diesel engine
No.of cylinders	1
IS rating at 1500 rpm	4.41 kW(bhp)
Bore	87.5mm
Stroke	110 mm
Cubic capacity	0.662 liters
Compression ratio	17.5:1
Fuel timing by spill (BTDC)	23 Deg

2.2 Fuel properties

Diesel is mixed with n-butanol in two different ratios first blend is B30 which containing of 70% diesel and 30% n-butanol, second blend is B45 which is containing of 55% diesel and 45% n-butanol. The blends properties are shown in Table 2. No separation observed in both blends.

Table 2. Properties of fuel

Property	Diesel	n Butanol (C_4H_9OH)	B30	B45
Cetane Index	50	~ 25	42.5	38.75
Kinematic Viscosity at (40°C) -- mm^2/sec	2.6	3.6	2.67	2.955
Density at (30°C - kg/m^3)	840	810	831	826.5
Calorific value (kJ/kg)	43000	33100	40596.16	39292
Oxygen content	0	21.6	6.46	9.72
Boiling point (°C)	180 - 360	117 - 118	161.1	154.8
Stoichiometric air – fuel ratio	15.0	11.2	13.85	13.2875
Latent heat of vaporization (kJ/kg)	250	585	350.5	400.7

3. Result and discussion

There is a reduction of all the properties by the addition of n-butanol to diesel except the oxygen content and heat of vaporization. Oxygen content and heat of vaporization are increasing with increasing of n-butanol in the blend.

3.1 Performance parameters

3.1.1 Brake thermal efficiency

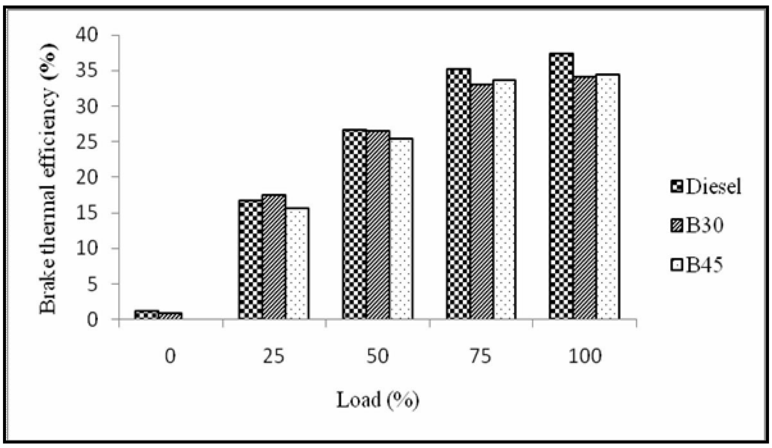

Figure 2. Brake thermal efficiency

Figure. 2 show the brake thermal efficiency of the blends and neat diesel fuel. It is showing that for both blends there is an increasing of BTE with the increase of the load. But at all loads it is lesser than that of neat diesel, except at 25% load for the blend B30 it is higher than that of neat diesel by around 5% and at 50% load it is similar to diesel. The decrease of BTE of the blends than neat diesel may be due to short combustion time for the blends to combust.

3.1.2 Brake specific fuel consumption

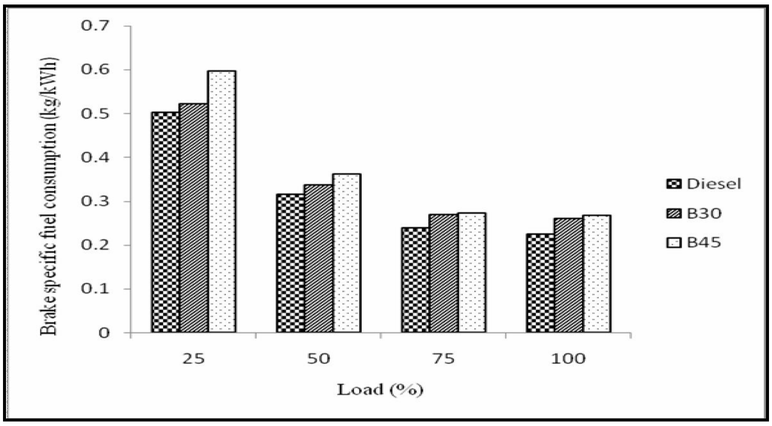

Figure 3. **Brake specific fuel consumption**

Brake specific fuel consumption of the blends and neat diesel fuel are shown in figure 3. It is showing that there is increase of BSFC of blends at all loads compared to neat diesel fuel, with increasing being higher the higher the ratio of n-butanol in the blend. This is due to lower cetane number and lower calorific value of n-butanol which lead to long premixed combustion and due to that more fuel must be injected to achieve same power which increase the consumption of the fuel.

3.2 Emission parameters

3.2.1Carbon monoxide emissions

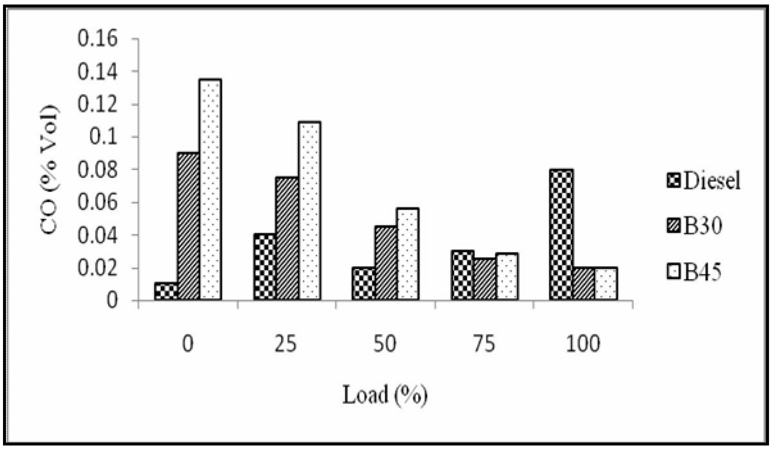

Figure 4.**Carbon monoxide emissions**

CO emissions for the blends fuel and neat diesel are presented in figure 4. It is observed that there is reduction in CO emissions for bothblends after 50% of load. There is a reduction of CO emissions with increasing of the load for all blends. The reason for the increase of CO emissions at lower loads is due to the higher latent heat of vaporization of the blends compared to diesel led to poorer air/fuel mixture resulting in incomplete combustion.

3.2.2Hydrocarbons emissions

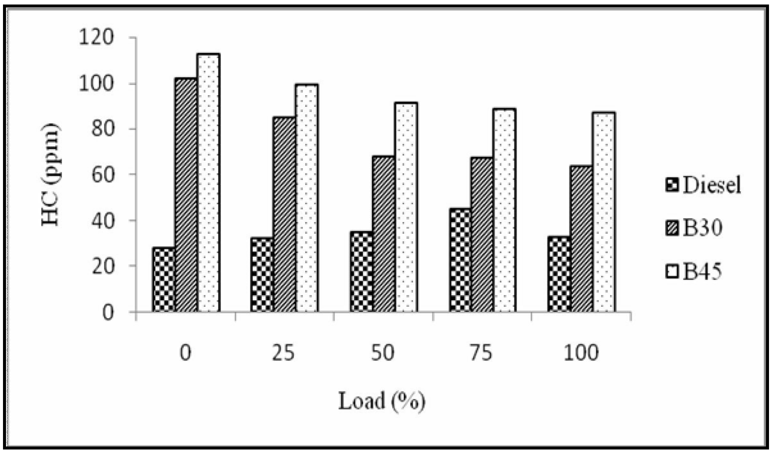

Figure 5. **Hydrocarbons emissions**

Figure5.showthe HC emissions of the fuel blends and neat diesel. It can be observed thatthe HC emissions of the blends are higher than that of neat diesel at all loads with increasing being higher the higher the ratio of n-butanol in the blend. However, as the load increases there is a decrease of HC emissions as the average temperature of the combustion chamber are higher for the blends compared to diesel. Also, the blends are having longer ignition delay as the cetane number is lower than diesel.

3.2.3Oxides of nitrogen emissions

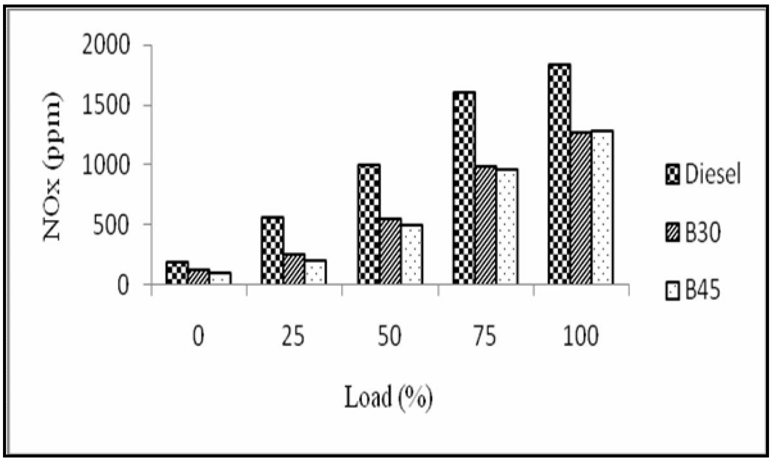

Figure 6.**Oxides of nitrogen emissions**

Figure 6.shows the NO_x emissions for the fuel blends and neat diesel. It is showing that at all loads the NO_x emissions of the fuel blends are lesser than that of neat diesel fuel. That due to leaner combustion of blends compared to diesel.Also the heat of vaporization of the blends are higher than diesel which led to the cooling effect reducing the combustion temperature and thereby resulting in lesser NO_x emissions.

4. Conclusion

The performance and emission characteristics of blends B30 and B45 have been conducted analysis has been made in comparison with diesel in diesel engine .the result shows that at full load:

- There is reduction in BTE by around 8.6%.
- The BSFC is increased by around 18% for B30, and around 22% for B45.
- There is reduction in CO emissions by around 75% for both blends.
- There is increase in HC level for both blends.

- There is reduction in NO_x emissions for both blends by around30%.

Nomenclature

B3070% Diesel And 30% Of n-Butanol
B4555% Of Diesel And 45% n-Butanol
CO Carbon Monoxide in ppm
HC Hydrocarbons in ppm
NO_x Oxides Of Nitrogen in ppm
HRR Heat Release Rate in kJ/m^3degree
TFC Total Fuel Consumption in kg/hr
BP Brake Power in kW
BTE Brake Thermal Efficiency in %
BSFC Brake Specific Fuel Consumption in kg/kW-hr.
EGR Exhaust Gas Recirculation
CNG Compressed Natural Gas
LPG Liquefied Petroleum Gas

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