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Improvement of Engine Performance and Emissions with Ethyl Hexyl Nitrate and Diesel-Biodiesel Blends

K.Venkateswarlu [*1], K.Ramakrishna[*], K.Vijaya Kumar[*]

Abstract – *Diesel-biodiesel blends improve the performance and reduce the emission effects in a compression ignition engine except NO_x. Cetane improvers reduce the ignition delay, which in turn reduces the combustion temperatures thereby reduces NO_x emissions. The present work was aimed at an experimental investigation of Ethyl Hexyl Nitrate (EHN) as an additive to the diesel-biodiesel blends. Experiments were conducted on a 4-stroke single cylinder diesel engine by varying the percentage by volume of EHN in diesel-biodiesel blends. The effect of EHN on Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC), cylinder pressure and exhaust emissions was studied. It is found that cylinder pressure was lower at higher EHN percentage which was accompanied by an increase in BTE and smoke density. Further CO and NO_x emissions were reduced with increase in EHN percentage.*

Keywords – Additives, biodiesel, brake thermal efficiency, EHN, emissions.

1. INTRODUCTION

Biodiesel is a viable alternative to petroleum diesel since the performance of biodiesel fuelled diesel engine is close to diesel and furthermore emissions are also low except NO_x [1]. Diesel-biodiesel blends require additives for improving the lubricity, ignition and better mixing. Additives used are oxygenates and cetane improvers which are used in unmodified and coated engines. The addition of oxygenates to petroleum fuels has been increasing due to advantages like better combustion and lower exhaust emissions. So many oxygenates like ethanol, I-propanol, I-butanol and I-pentanol have been used by various researchers which improved the performance parameters with reduction of particulates, and this reduction is in proportion to the oxygenate percentage. However exhaust emissions like HC and NO_x increase with some oxygenates [2]-[8]. Addition of ethanol as an oxygenate additive and dodecanol as the solvent to diesel shows higher brake specific fuel consumption with slight increase in brake thermal efficiency, however higher ethanol content reduces cetane number of diesel [9]. Isobutanol–diesel fuel blends show marginal improvement in BTE with reduction in brake power, accompanied by an increase in BSFC in proportion to the isobutanol content in the blends. CO and NO_x emissions decreased while HC emissions increased compared to diesel fuel [10]. P-series glycol ethers were effective in reducing hydrocarbon, carbon monoxide, and particulate matter emissions [11]. The addition of Di Methyl Carbonate (DMC) to diesel fuel increases efficiency marginally with reduction in NO_x emissions while PM and soot emissions were reduced considerably [12], [13]. However low cetane number and high latent heat of vaporization while low viscosity and insufficient lubricity of Di Methyl Ether (DME) are the limiting factors of DMC as an additive [14]. Additives Diethylene Glycol Dimethyl Ether and liquid cerium showed significant improvements in BSEC and exhaust emissions [15]. Bio-additives (matter extracted from palm oil) as gasoline additives at various percentages (0.2%, 0.4% and 0.6%) showed improvement in fuel economy and exhaust emissions of SI engine [16]. Methyl-ester of Jatropha oil diesel blends with Multi-DM-32 diesel additive showed comparable efficiencies, lower smoke, CO_2 and CO [17]. Additives with coated engines improved efficiency, in addition to the increase in cylinder pressure, reduction in NO_x and reduction in maximum heat release rate. Thermal Barrier Coated (TBC) DI diesel engine with fuel additives (di-isopropyl ether) with neat diesel fuel in the ratio between 0.5% and 2.0% reduced the smoke density and NO_x emission of the engine exhaust [18]. 1-4 dioxane, an ether derived from alcohol as an additive to the diesel fuel reduced smoke density with slight increase in NO_x and drop in fuel economy. Brake thermal efficiency is improved marginally and smoke reduced significantly with the blends when compared to neat diesel for TBC engines [19]. Cetane improvers, another class of additives reduce the ignition delay which aids in better cold starting, reduced NO_x emissions, and smoother engine operation [20], [21]. Ignition delay in engines also plays an important role in combustion performance [22]. These additives to diesel fuel reduced all regulated and unregulated emissions including NO_x emissions [23]. Cetane improver with oxygenate such as glycol ether reduced particulate, HC, and CO emissions [24]. Ethanol-diesel blends with EHN as additive increased BTE and reduced significantly the emissions like CO,THC, smoke, and particulates in CRDI diesel engine[25] and also decrease cylinder pressure, ignition delay, the maximum rate of pressure rise, and the combustion noise [26]. Ethanol-diesel blends with cetane improver with advanced fuel injection angle show a large decrease in exhaust smoke concentration and a small decrease in exhaust NO_x concentration [27]. The objective of this study was to investigate the performance, combustion and emission characteristics of

*Mechanical Engineering Department, K.L. University, Guntur, Andhra Pradesh, 522502 India.

[1]Corresponding author, Tel: + 91 9989841031
E-mail: chaitu9903@yahoo.co.in; kvklu@kluniversity.in.

diesel engine with diesel-biodiesel blends with cetane improver EHN as an additive.

2. EXPERIMENTAL SET UP AND PROCEDURE

2.1 Experimental set up

The engine as shown in Figure1 was a computerized single cylinder four stroke, naturally aspirated direct injection and water cooled diesel engine. The specifications of the test engine are given in Table 1. It was directly coupled to an eddy current dynamometer. The engine and the dynamometer were interfaced to a control panel which is connected to a computer. This engine was used for evaluation of performance, combustion and emission characteristics of fish oil biodiesel and diesel blends. Engine soft version 2.4 was used for recording the test parameters such as fuel flow rate, temperatures, air flow rate, load etc, and for calculating the engine performance characteristics such as brake thermal efficiency, brake specific fuel consumption and volumetric efficiency.

Table1. Specifications of the test engine.

Particulars	Specifications
Make	Kirloskar
Rated power	5 Hp
Bore	80 mm
Stroke length	110 mm
Swept volume	562 cc
Compression ratio	16.5:1
Rated speed	1500 rpm

Fig. 1. Test engine.

2.2 Test Fuels

For experimental investigation, Biodiesel derived from fish oil was mixed with diesel in varying proportions such as 20%, 30% and 40% by volume and two sets of samples of diesel-biodiesel blendes with cetane improver, 2-Ethyl Hexyl Nitrate with chemical formula $C_8H_{17}NO_3$ were prepared. First set of samples contains diesel-biodiesel blends with cetane improver EHN 0.5 % by volume while second set of samples contains diesel-biodiesel blends with EHN 1% by volume. Diesel-biodiesel blends with cetane improver were designated as B20CI, B30CI, B40CI (*i.e.* B20CI implies biodiesel 20% with cetane improver). The properties of test fuels are given in Tables 2 and 3. Table 2 compares the properties of neat diesel and blends with EHN 0.5%, while Table 3 compares the diesel and blends with EHN 1%, respectively.

2.3 Experimental Procedure

The engine was operated at a constant speed of 1500 rpm with an injection advance of 27°. Five engine loads with BMEP values of 0.9, 1.8, 2.7, 3.62 and 4.52 bars were chosen for engine experiments. The first stage of experiment was performed with pure diesel at different loads from no-load to full load at constant speed. Engine loads were adjusted by eddy current dynamometer. The second stage of experiment was done using various blends of diesel-biodiesel with cetane improver EHN

0.5%.The third stage of experiment was performed using diesel-biodiesel blends with EHN 1%. The exhaust gas temperature, water inlet and outlet temperatures, airflow rate, fuel consumption, brake power, brake specific fuel consumption, torque, combustion characteristics like pressure rise and heat release were recorded through the software at various loads. Exhaust emissions CO, and NO_x were recorded by the flue gas analyzer while smoke density was measured with Hartridge smoke meter.

Table 2. Properties of test fuels (EHN 0.5%).

Properties	Density (g/cm^3)	Viscosity (centistokes)	Flash point (°C)	Fire point (°C)
Diesel	0.83	3.15	57	60
B20CI0.5	0.841	4.842	37	42
B30CI0.5	0.846	5.142	40	43
B40CI.5	0.851	5.437	42	46

Table 3. Properties of test fuels (EHN 1%).

Properties	Density (g/cm^3)	Viscosity (centistokes)	Flash point (°C)	Fire point (°C)
Diesel	0.83	3.15	57	60
B20CI1	0.854	5.129	35	40
B30CI1	0.859	5.389	39	42
B40CI1	0.863	5.716	41	46

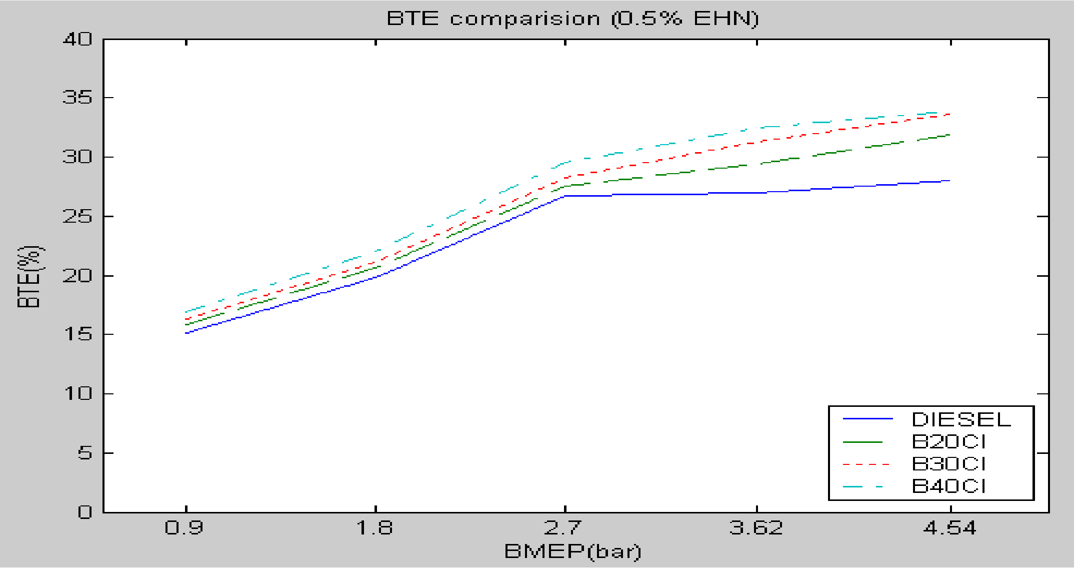
3. RESULTS AND DISCUSSION

3.1 Performance Analysis

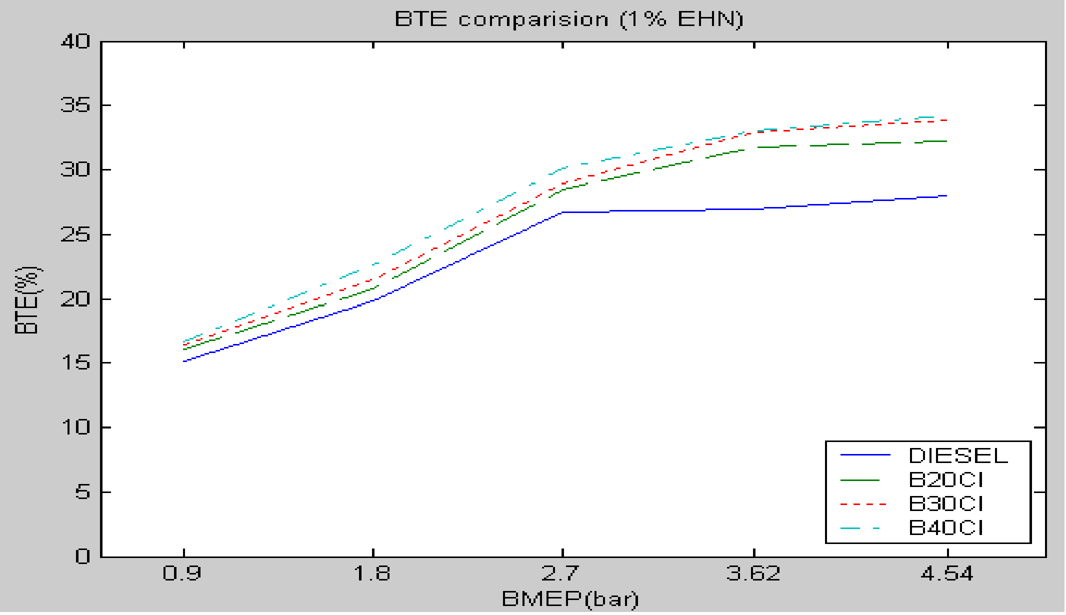
Performance parameters considered in this study such as BTE, BSFC and exhaust gas temperature values of blends against pure diesel are compared at different BMEP values of 0.9, 1.8, 2.7, 3.62 and 4.52 bars respectively. Figures 2(a) and (b) show the variation of BTE with Brake Mean Effective Pressure (BMEP) for various biodiesel blends with 0.5% and 1% EHN respectively. The increase in BTE with the blends was marginal at low BMEP values while it increases considerably at higher BMEP values, BTE further increases with EHN percentage when compared to pure diesel. However there was negligible improvement observed in BTE with increase in EHN percentage. 15% to 20% improvement in BTE was observed at maximum BMEP with 0.5% and 1% EHN additive in diesel-biodiesel blends respectively against pure diesel. This is due to the fact that the rapid combustion caused by the addition of cetane improver [24]. Figure 3(a) and (b) shows the variation of Brake Specific Fuel Consumption (BSFC) with BMEP for diesel and various blends. It is observed from these figures that the BSFC of the different fuel blends was different since the energy contents of the blends are different further more; the addition of EHN causes the BSFC to vary. BSFC was lower for all the blends with 0.5% and 1% EHN than that of pure diesel. This can be attributed to the improvement in combustion due to the addition of cetane improver to the blends. Figures 4(a) and (b) show the variation of exhaust gas temperature with BMEP for diesel and various blends. Exhaust gas temperature decreases with the increase in blend percentage and EHN as well. This was due to the addition of cetane improver which aids in better utilization of heat and reduced combustion temperatures and furthermore the blends have less energy content which also results in reduced combustion temperatures.

3.2 Combustion Analysis

Combustion analysis results such as cylinder pressure versus crank angle are shown in Figure 5. Maximum cylinder pressure decreases with the blends and decreases further with EHN. It can also be seen that the addition of cetane improver causes the cylinder pressure traces of the blends shift toward BDC by some crank angle degrees when compared to diesel which demonstrates that they ignite earlier than diesel and finish the combustion earlier than diesel and also different pressure traces for different blends before TDC. This may be attributed to the addition of EHN which decreases ignition delay and reduces the accumulation of unburned fuel in the premixed phase of combustion which results in reduction in cylinder pressure and delay period, these results also coincide with the results presented in [27].

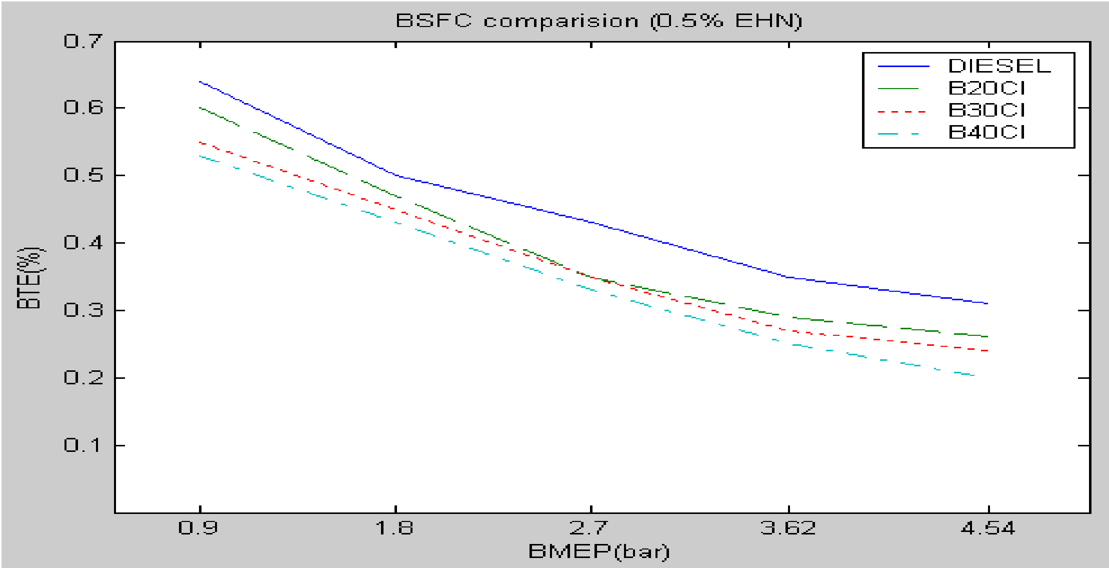


(a) 0.5% EHN

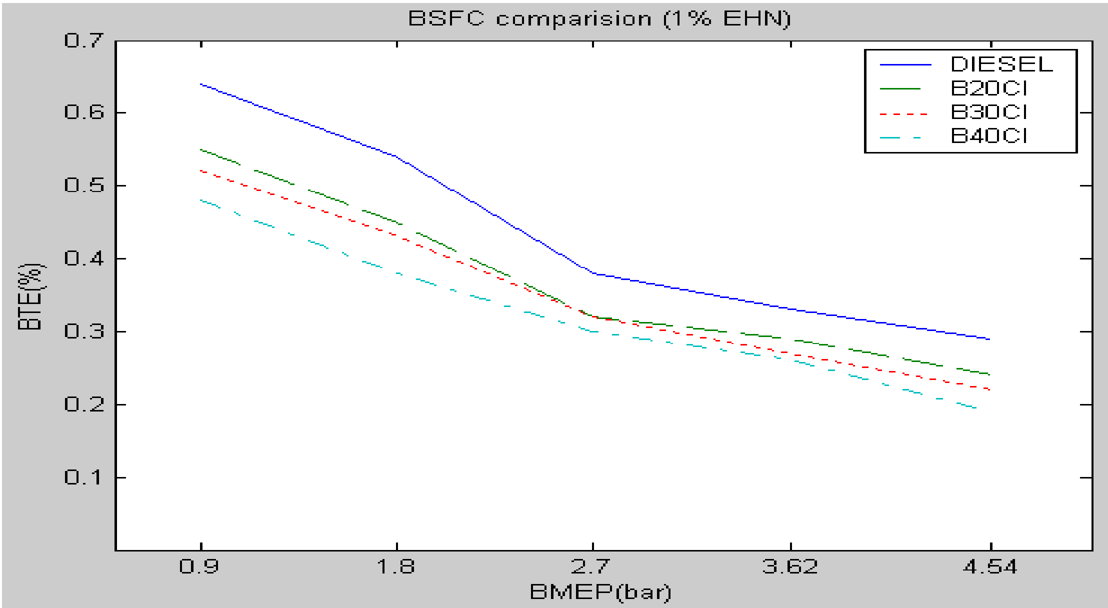


(b) 1% EHN

Fig. 2. Variation of brake thermal efficiency with BMEP for different fuel blends.

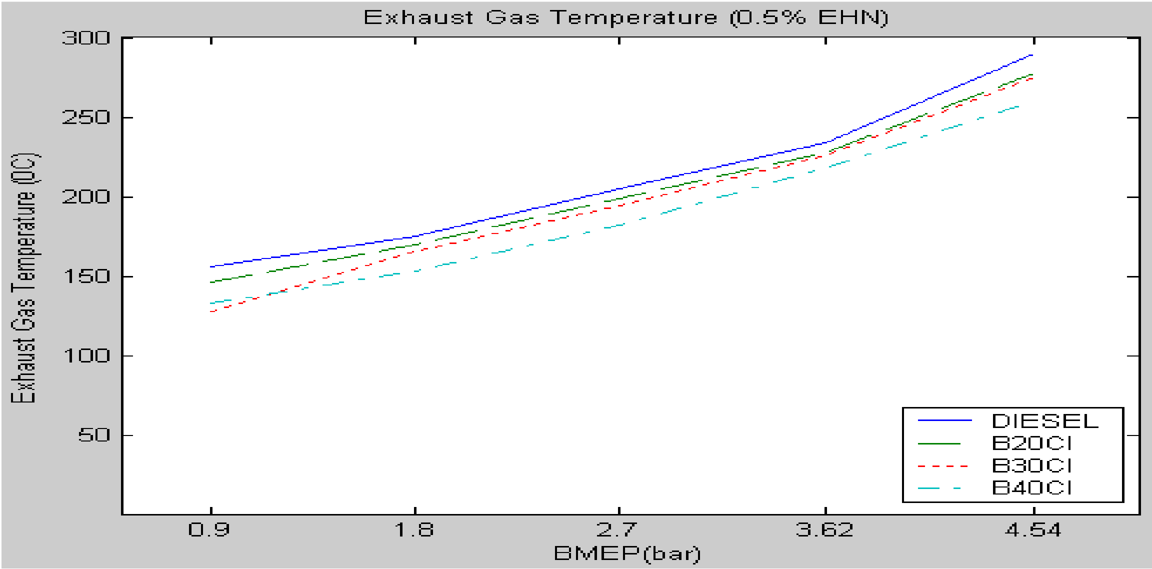


(a) 0.5% EHN

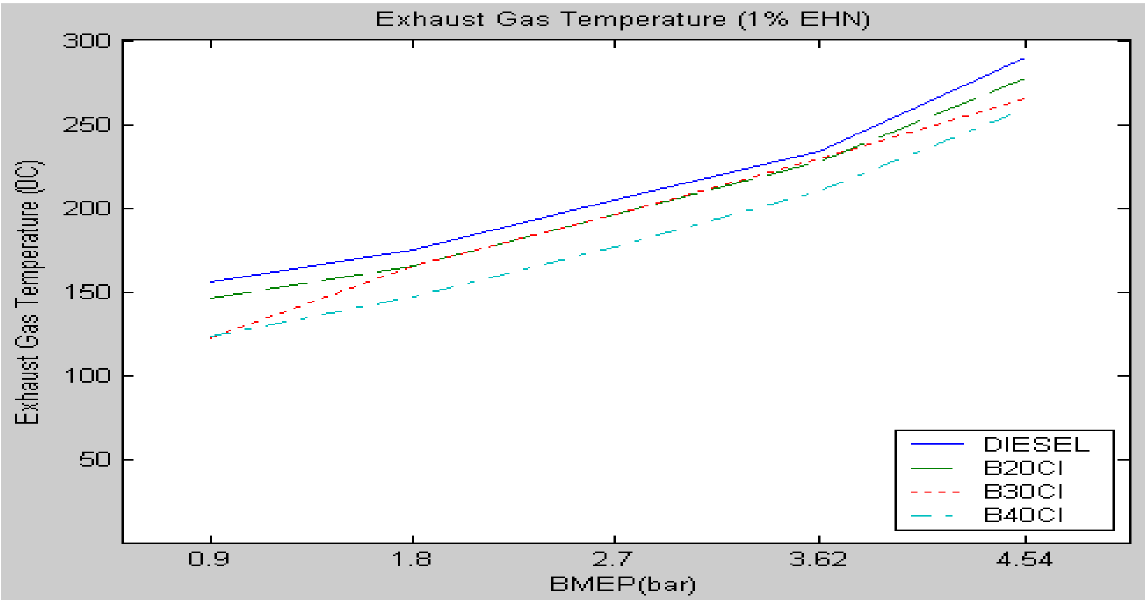


(b) 1% EHN

Fig. 3. Variation of brake specific fuel consumption with BMEP for different fuel blends.

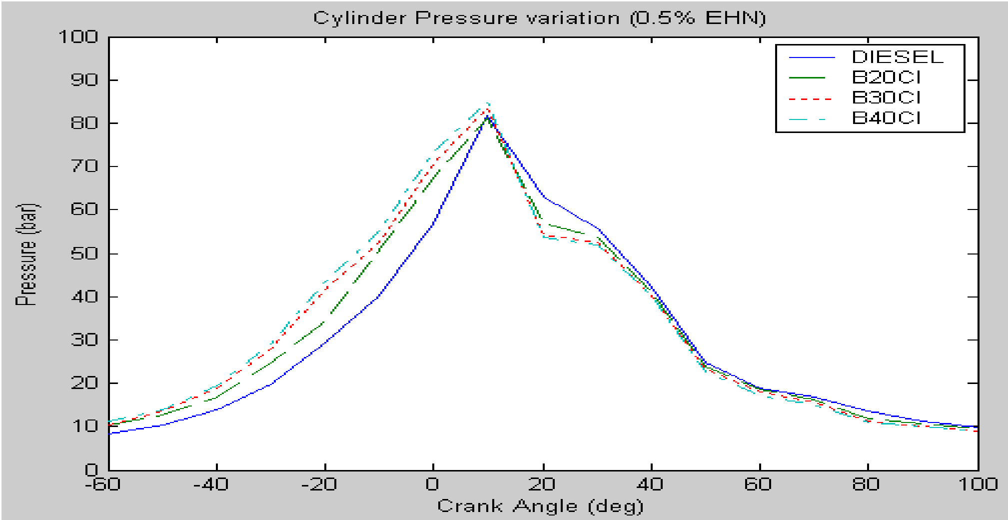


(a) 0.5% EHN

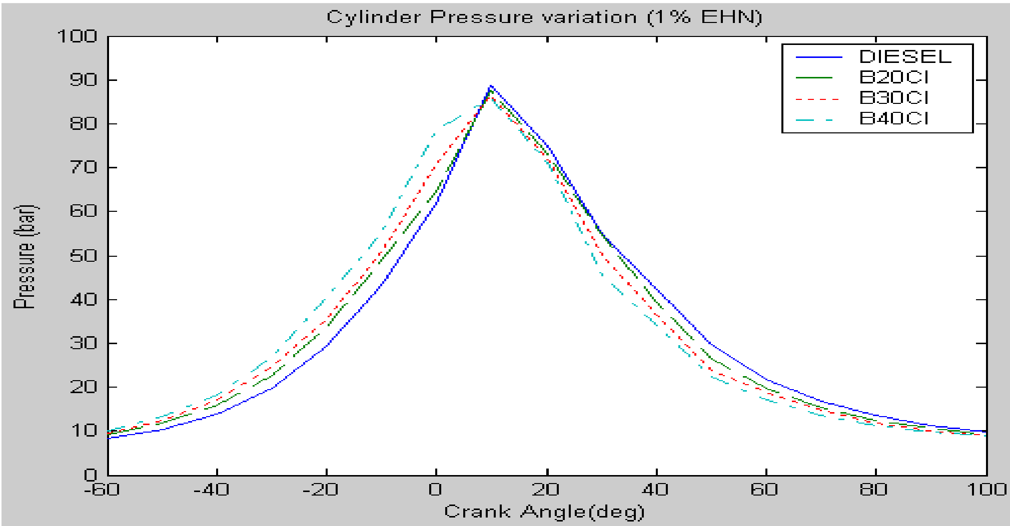


(b) 1% EHN

Fig. 4. Variation of exhaust gas temperature with BMEP for different fuel blends.



(a) 0.5% EHN

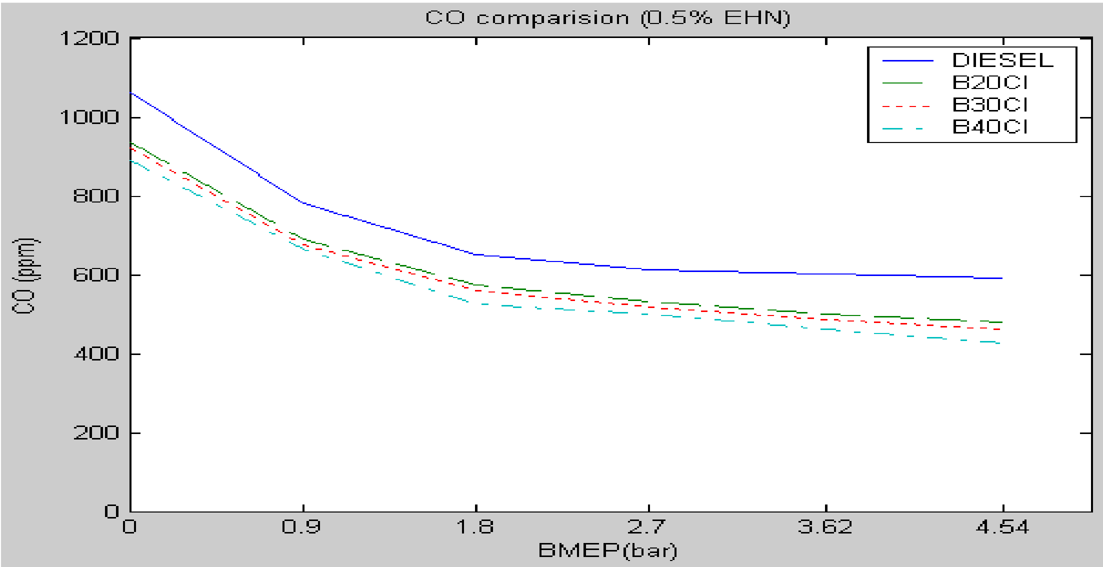


(b) 1% EHN

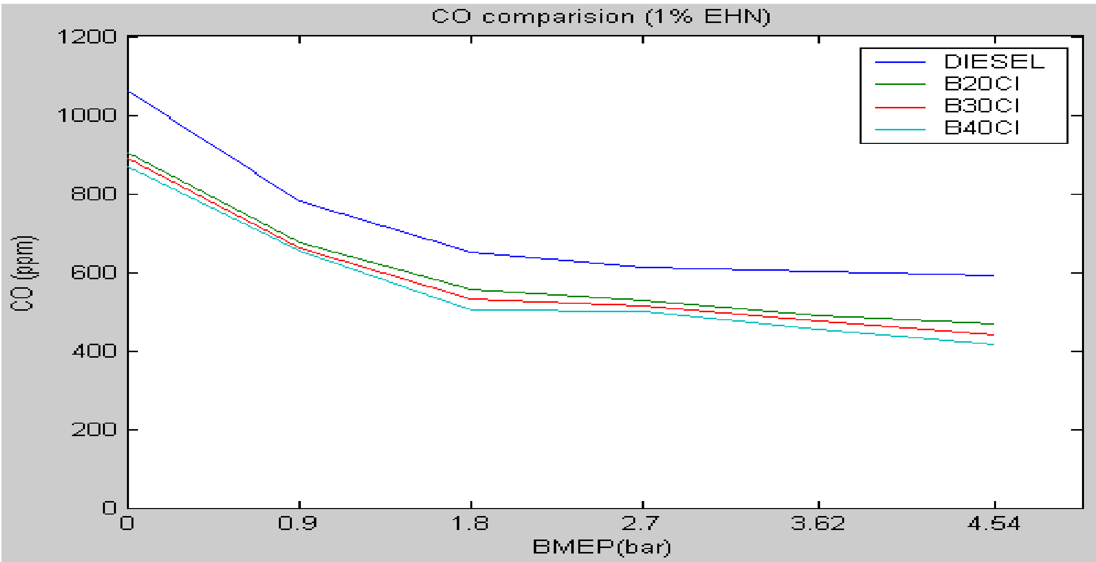
Fig. 5. Variation of cylinder pressure with crank angle at maximum BMEP for different fuel blends.

3.3 Exhaust Emission Analysis

Figures 7 (a) and (b) show the variation of CO emissions with BMEP for both 0.5% and 1% EHN respectively. CO emissions decreased with all the blends when compared to diesel and further decrease with EHN percentage. CO emissions show a reduction of 29% and 38% with the blends with 0.5% and 1% EHN respectively. Cetane improver improves ignition quality which allows better combustion which results in less CO than diesel. Figure 8 (a) and (b) shows the variation of NO_x emissions with BMEP. The addition of EHN increases cetane number of the blends which shortens the ignition delay and premixed combustion as a result of which NO_x reduces. NO_x emissions decrease by 3.7% and 4.5% with the blends with 0.5% and 1% EHN respectively. Figures 9 (a) and (b) show the variation of smoke density with BMEP. Smoke decreases significantly with the blends when compared to diesel which however increases with EHN. Smoke decreased by 48% and 38% respectively with 0.5% and 1% EHN. The reason for increase in smoke with increase in EHN may be attributed to the increase in cetane number which reduces non-sooting premixed burn duration due to shorter ignition delays [27].

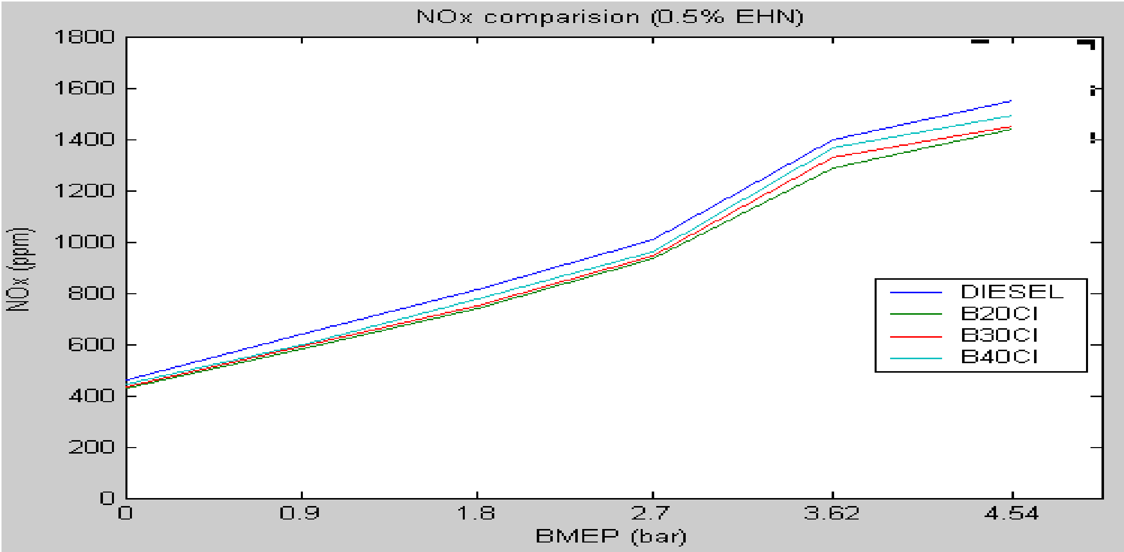


(a) 0.5% EHN

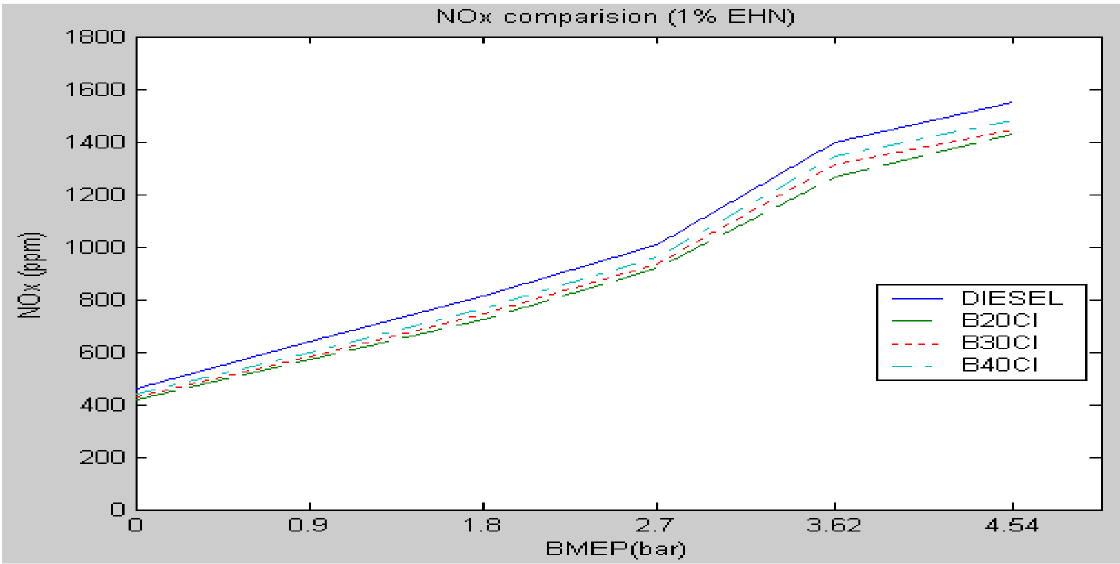


(b) 1% EHN

Fig. 6. Variation of CO emissions with BMEP for different fuel blends.

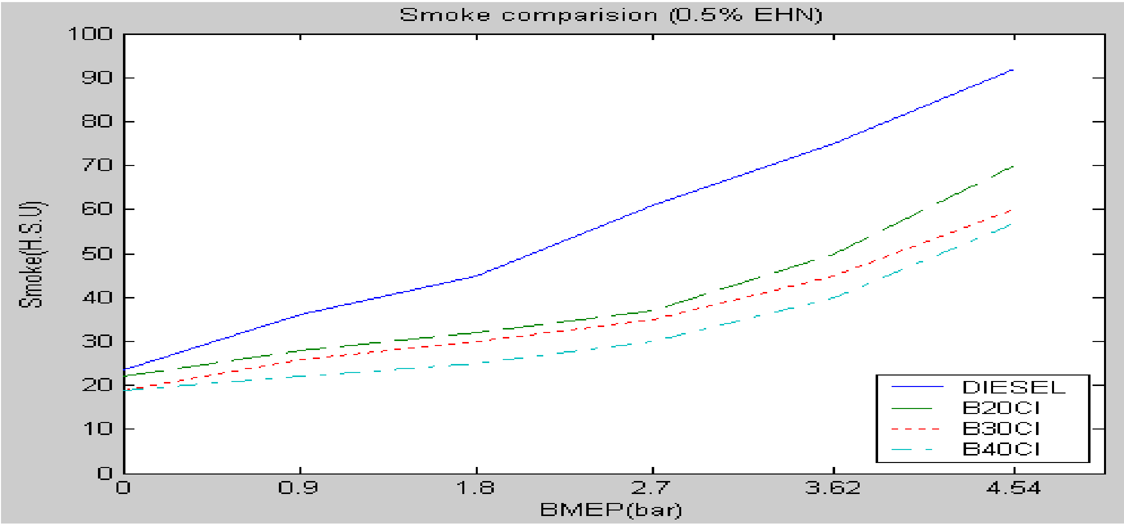


(a) 0.5% EHN

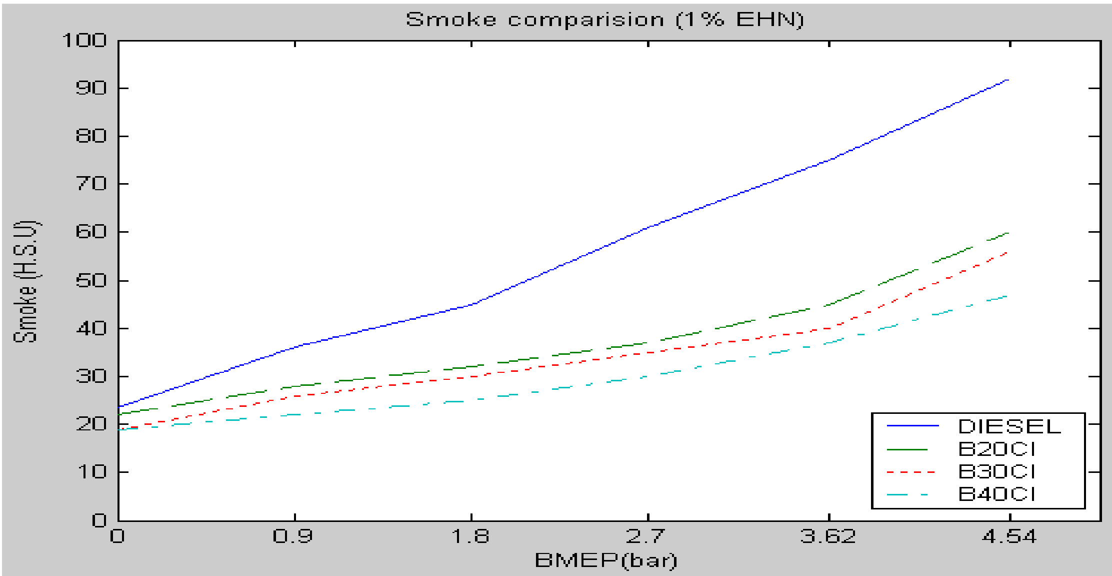


(b) 1% EHN

Fig.7. Variation of NO_x emissions with BMEP for different fuel blends



(a) 0.5% EHN



(b) 1% EHN

Fig.8. Variation of smoke density with BMEP for different fuel blends

4. CONCLUSIONS

The conclusions from present experimental investigation on a diesel engine with EHN as an additive to diesel-biodiesel blends operated at a constant speed of 1500 rpm are summarized as follows:

1. Brake thermal efficiency increases with increase in percentage of blends when compared to the conventional diesel fuel. However with increase in EHN percentage the improvement is nominal.
2. Brake specific fuel consumption decreases with increase in blend percentage with EHN when compared to pure diesel.
3. Maximum pressure decreases with increase in the percentage of blend.
4. Increase in EHN percentage decreases CO and NO_x emissions, increases smoke density.
5. The rate of improvement using biodiesel blends decreases with increase in percentage of biodiesel and it is found that the improvement is marginal with 40% when compared to 30% blend. Hence the recommended blend is B40CI.
6. Though EHN 1% reduces the NO_x emissions, it can be offset by an increase in smoke density and marginal improvement in BTE. Hence, higher

EHN percentage *i.e.* beyond 0.5% may not be advisable.

However these conclusions are based on the experimental results of the engine running at a constant speed of 1500 rpm from no load to full load and may not agree with the other engine speeds.

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