

Engine Performance and Emissions with Ethanol and Diesel-Biodiesel Blends

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Abstract - Diesel-biodiesel blends improve the performance and reduce the emission effects in a compression ignition engine except NO_x . Cetane improves 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 Ethanol (ETN) 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 ETN in diesel-biodiesel blends. The effect of ETN 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 ETN percentage which was accompanied by an increase in BTE and smoke density. Further CO and NO_x emissions were reduced with increase in ETN percentage.

Keywords: Additives, Biodiesel, Brake thermal efficiency, ETN, 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]. 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. The

objective of this study was to investigate the performance, combustion and emission characteristics of diesel engine with diesel-biodiesel blends with cetane improver ETN 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.



Fig-1: diesel engine test rig
Table 2 specifications of the 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 blends with cetane improver, Ethanol with were prepared. First set of samples contains diesel-biodiesel blends with cetane improver ETN 0.5 % by volume while second set of

samples contains diesel-biodiesel blends with ETN 1% by volume. Diesel-biodiesel blends with cetane improver were designated as B20CI, B30CI, and 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 ETN 0.5%, while Table 3 compares the diesel and blends with ETN 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 ETN 0.5%.The third stage of experiment was performed using diesel-biodiesel blends with ETN 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.

Specifications of the Test Engine	
Particulars	Specifications
Make	Kirloskar
Rated Power	3.7 kw(5hp)
Bore	80 mm
Stroke Length	110 mm
Swept volume	562 cc
Compression ratio	Compression ratio 16.5:1

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

Properties	Density (g/cm ³)	Viscosity (centistokes)	Flash point (°C)	Fire point (°C)
Diesel	0.83	3.15	57	60
B20C1	0.854	5.129	35	40
B30C11	0.859	5.389	39	42
B40C11	0.863	5.716	41	46

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

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

3. RESULTS AND DISCUSSION

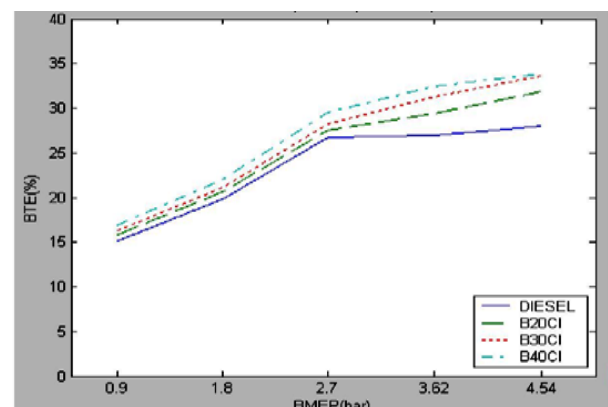
3.1 Performance Analysis

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% ETN 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 ETN percentage when compared to pure diesel. However there was negligible improvement observed in BTE with increase in ETN percentage. 15% to 20% improvement in BTE was observed at maximum BMEP with 0.5% and 1% ETN 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. 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 ETN causes the BSFC to vary. BSFC was lower for all the blends with 0.5% and 1% ETN than that of pure diesel. This can be attributed to the improvement in

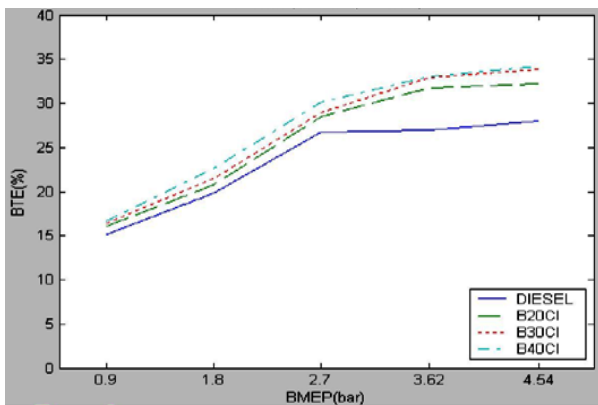
combustion due to the addition of cetane improver to the blends. Figures 4(a) and (b) show the variation of exhaust gas temperature with BMEP for diesel and various blends. Exhaust gas temperature decreases with the increase in blend percentage and ETN as well. This was due to the addition of cetane 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 ETN. 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 ETN 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.

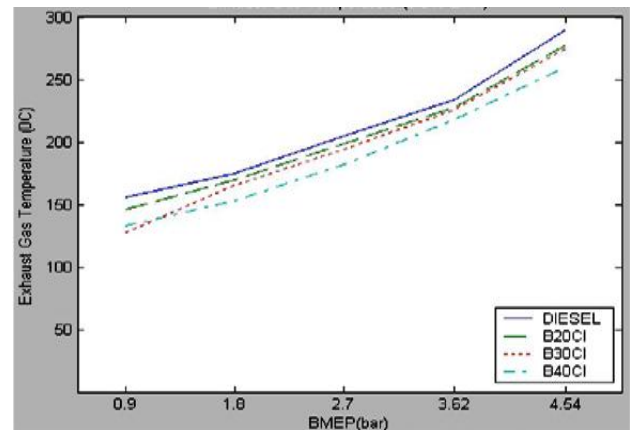


(a) 0.5% ETN



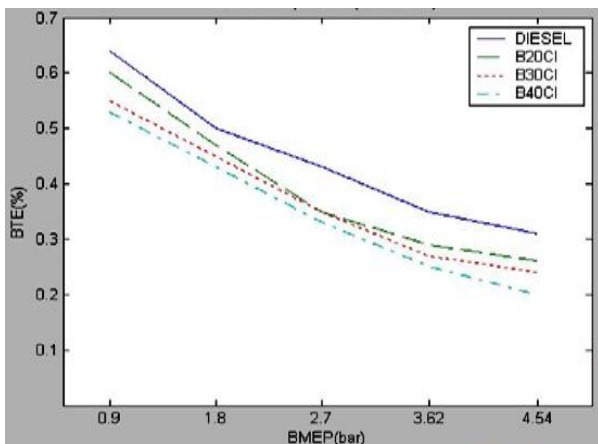
(b) 1% ETN

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

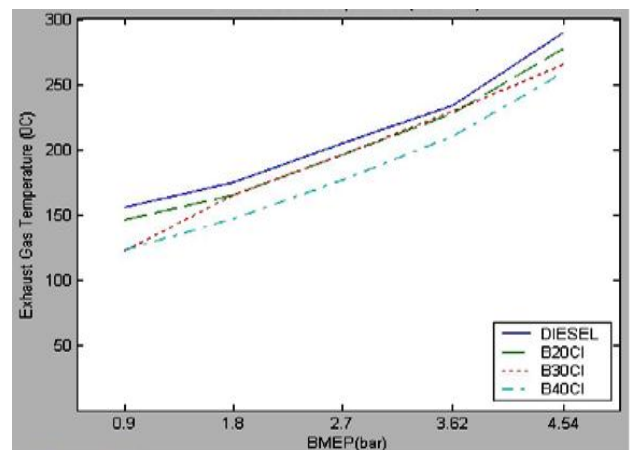


(a)

0.5% ETN



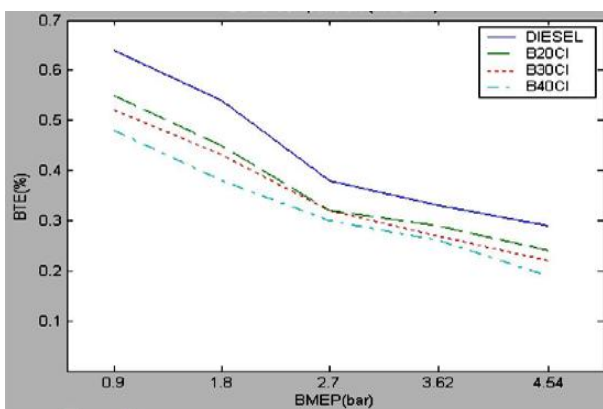
(a) 0.5% ETN



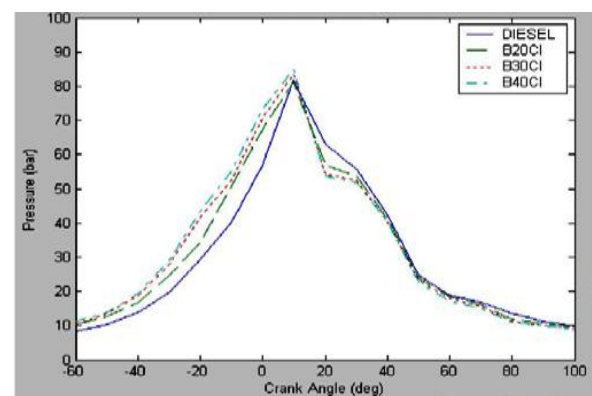
(b)

1% ETN

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

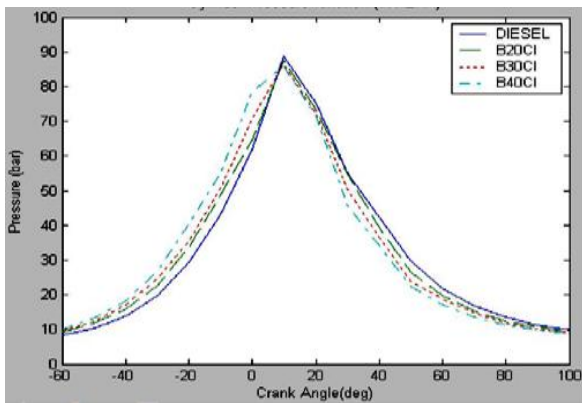


(b) 1% ETN



(a) 0.5% ETN

Fig.2. variation of brake specific fuel consumption with BMEP for different fuel blends

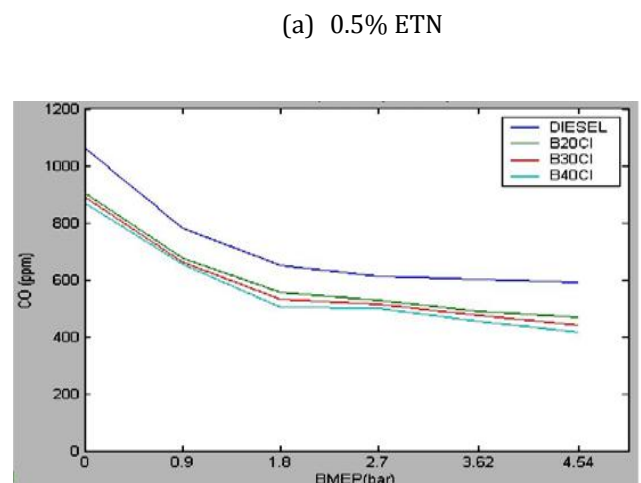
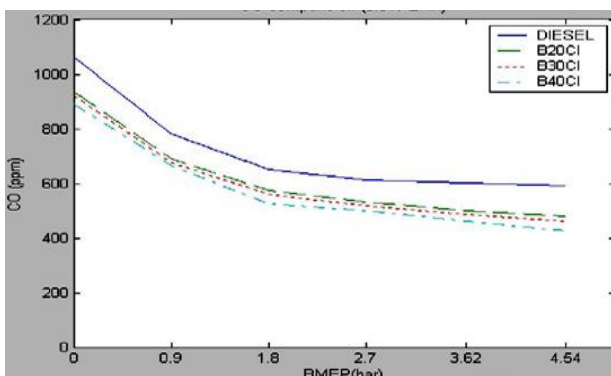


(b) 1% ETN

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

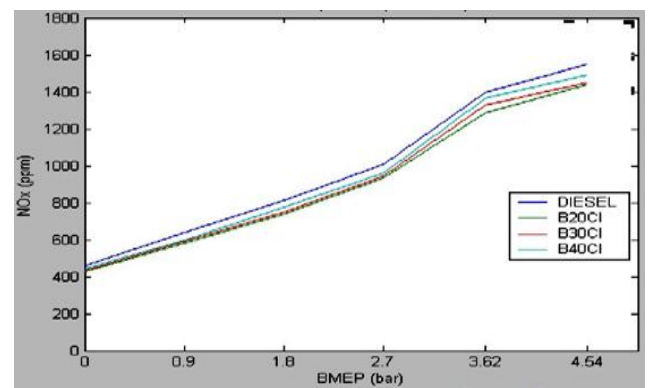
3.3 Exhaust Emission Analysis

Figures 7 (a) and (b) show the variation of CO emissions with BMEP for both 0.5% and 1% ETN respectively. CO emissions decreased with all the blends when compared to diesel and further decrease with ETN percentage. CO emissions show a reduction of 29% and 38% with the blends with 0.5% and 1% ETN 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 ETN 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% ETN 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 ETN. Smoke decreased by 48% and 38% respectively with 0.5% and 1% ETN. The reason for increase in smoke with increase in ETN may be attributed to the increase in cetane number to shorter ignition delays. Which reduces non-sooting premixed burn duration due.

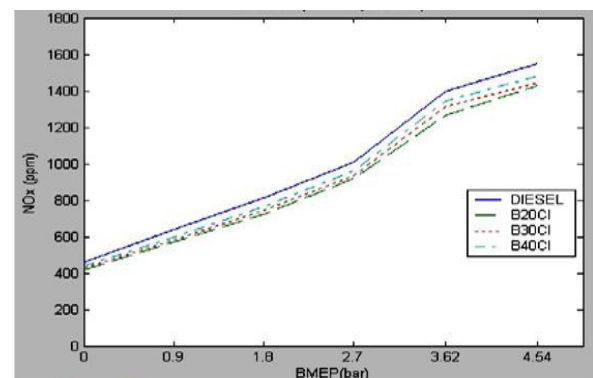


(b) 1% ETN

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

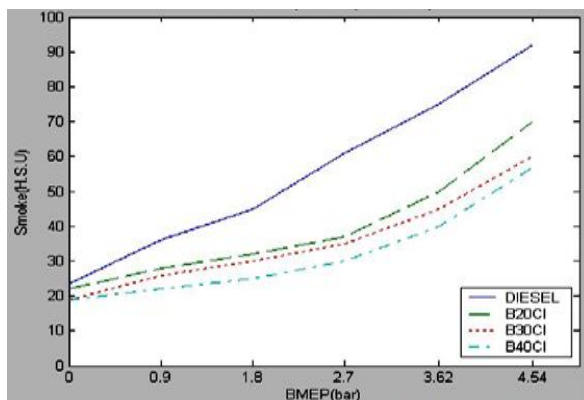


(a) 0.5% ETN

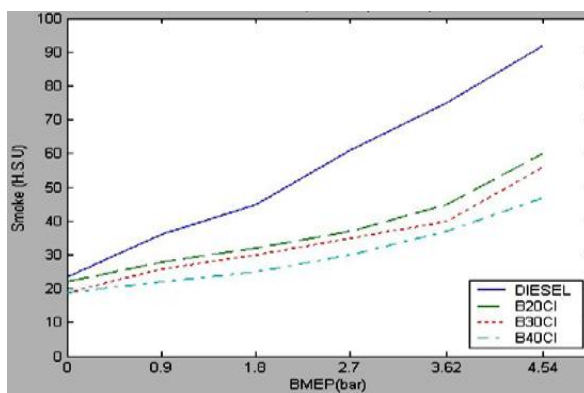


(b) 1% ETN

Fig.7. variation of NOx emissions with BMEP for different fuel blends



(a) 0.5% ETN



(b) 1% ETN

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 ETN 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 ETN percentage the improvement is nominal.
2. Brake specific fuel consumption decreases with increase in blend percentage with ETN when compared to pure diesel.
3. Maximum pressure decreases with increase in the percentage of blend.
4. Increase in ETN 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 ETN 1% reduces the NO_x emissions, it can be

offset by an increase in smoke density and marginal improvement in BTE. Hence, higher ETN percentage *i.e.* beyond 0.5% may not be advisable.

7. 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.

5. REFERENCES

1. Wang X.G., Zheng B., Huang Z.H., Zhang N., Zhang Y.J. and Hu E.-J., 2010. Performance and emissions of a turbocharged, high-pressure common rail diesel engine operating on biodiesel/diesel blends. In *Proceedings of I Mech E, Part D: J. Automobile Engineering*, Vol. 225.
2. Frijters P.J.M. and R.S.G. Baert. 2004. Oxygenated fuels for clean heavy-duty diesel engines. In *Proceedings of VAFSEP*. Dublin, Ireland, 6-9 July.
3. Michikawauchi R., Tanno, S., Ito, Y. and Kanda, M., 2011. Combustion improvement of diesel engine by alcohol addition - investigation of port injection method and blended fuel method. *SAE International Journal on Fuels and Lubrication*. 4:48-57.
4. Sivalakshmi S. and T. Balusamy. 2011. Effects of oxygenated organic compounds Neem oil blends on the performance and exhaust emissions of a DI diesel engine. *SAE Paper Number: 2011-01-0331*.
5. [5] Srinivasan A.C. and C.G. Saravanan, 2010. Study of Combustion Characteristics of an SI Engine Fuelled with Ethanol and Oxygenated Fuel Additives. *Journal of Sustainable Energy and Environment* 85-91.
6. Balaji D., Govindarajan P. and Venkatesan., 2010. Influence of isobutanol blend in spark ignition engine Performance and emissions operated with gasoline and Ethanol. *International Journal of Engineering Science and Technology* 2(7): 2859-2868.
7. Yao C.D., Zhang Z.H., Xu Y.L. and Huang Y., 2008. Experimental investigation of effects of bio-additives on fuel economy of the gasoline engine. *Science in China Series E: Technological Sciences*.
8. Jagadish D., Kumar P.R. and Murthy K., 2011. The effect of supercharging on performance and emission characteristics of C.I. engine with diesel-ethanol-ester blends. *Thermal Science International Scientific Journal* 15(4):1165-1174.
9. Cheung C.S., Yage D. and Huang Z., 2008. Experimental investigation of regulated and unregulated emissions from a diesel engine fuelled with ultra low-sulfur diesel fuel.

Atmospheric Environment 42:8843–8851.

13. Karabektas M. and M. Hosoz. 2009. Performance and emission characteristics of a diesel engine using isobutanol–diesel fuel blends. *Renewable Energy* 34(6):1554-1559.
14. Karas L.J. Kesling Jr., H.S., Liotta Jr., F.J., Nandi M.K. Low emission oxygenated diesel fuel. *ARCO Chemical Company, Research and Development*
15. Report No.3801. West Chester Pike Newtown Square, PA 19073-2387.
16. Zhang G.D., Liu H.X., Xia X.X., Zhang W.G. and Fang J.H., 2005. Effects of dimethyl carbonate fuel additive on diesel engine performances. In
17. *Proceedings of IMechE Part D: Journal of Automobile Engineering* 219(D):13904.
18. Nibin T., Sathiyagnanam A.P., Sivaprakasam S. and Saravanan C.G., 2005. Investigation on emission characteristics of a diesel engine using oxygenated fuel additive. *IE (I) Journal MC* 86:51-54.
19. Ribeiro N.M., Pinto A.C., Quintella C.M., da Rocha G.O., Teixeira L.S.G., Guarieiro L.L.N., do Carmo Rangel M., Veloso M.C.C., Rezende M.J.C., da Cruz R.S., de Oliveira A.M., Torres E.A. and de Andrade J.B., 2007. The role of additives for diesel and diesel blended (ethanol or biodiesel) fuels: a review. *Energy and Fuels* 21:2433-2445.

BIOGRAPHIES



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