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Research Article

The Role of Oxygenated Fuel Additive (DEE) along with Mahuva Methyl Ester to Estimate Performance and Emission analysis of DI-Diesel Engine

P. Ramesh Babu[a*], K. Prasad Rao[a], B.V. Appa Rao[b]

[a]Department of Mechanical Engineering, GMR Institute of Technology, GMR Nagar, Rajam-532127, Srikakulam Dist. A.P, India.
[b]Dept. of Marine Engineering, AUCE (A),Andhra University, Visakhapatnam, A.P., India.
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Abstract

Particulate matter and oxides of nitrogen are the main pollutants in the tail pipe emissions of bio-diesel fueled engine. In this investigation Mahua methyl ester along with diethyl ether (DEE) used as fuel for the single cylinder DI-Diesel engine, analysis of performance and emission is presented. This paper presents an investigation into the effect of biodiesel blending on performance and emission characteristics of diesel engine. The effect of fuel additive was to control the emission from diesel engine and to improve its performance. But still the research work is going on the bio-diesels application is to make it environmental friendly. In this experiment DEE mixed with the MME at different proportion such as 3%, 5%, 10% and 15% tested at different loads on diesel engine. The addition of diethyl ether to the blends reduced the NOX emission at low and medium loads; however, at high loads the NOX emission was higher compared to diesel and lower compared to the corresponding biodiesel blend. The results obtained from the engine tests have shown a significant reduction in NOx emissions especially for DEE addition of more than 10% on a volume basis and a little decrease in smoke of DEE blends compared with neat MME. Smoke levels are decreased substantially with 15% DEE blend with MME at full load. The thermal efficiency rise and SFC are better in the case of 15% additive blend.

***Keywords**: Oxygenated fuels, Diethyl ether, Mahua methyl ester, physicochemical properties, viscosity, and specific gravity.*

1. Introduction

Researchers around the world are devoted to reduce such emissions with different ways. Fuel modification, modification of combustion chamber design and exhaust after treatment is the important means to alleviate such emissions. In this context, engine researchers are hunting suitable alternative fuels for diesel engine. Among different alternative fuels, oxygenated fuel is a kind of alternative fuel. The success of oxygenated gasoline has sparked interest in the use of oxygenated compounds as particulate matter (PM) emissions reducing additives in diesel fuel. The most widely used in diesel engines is the direct-injection (DI) combustion system because of its lower fuel consumption. In recent times the fuel economy and combustion control of the DI diesel engine have been improved by adopting several techniques. Biodiesel is a renewable one having comparable calorific value with diesel. It contains no sulphur, no aroma but has a higher cetane number. It emits carbon monoxide (CO) and unburnt hydrocarbons (HC) significantly less. However the NOx emission is higher compared to diesel due to higher oxygen content. Diethyl ether (DEE), an oxygenated additive can be added to diesel/ biodiesel fuels to suppress the NOx emission. DEE is an excellent ignition enhancer and has a low auto ignition temperature. It is an aid for cold starting and ignition improver for diesel water emulsion. Iranmanesh et al. found that 5% of DEE with diesel blend was the most effective combination based on performance and emission characteristics. As DEE is oxygenated fuel that has a very high Cetane number. Iranmanesh also reported lower smoke and THC emissions due to higher Cetane number and Oxygen content of DEE

Various researchers tried the blends of DEE with biodiesel to reduce emissions. The addition of DEE with rubber seed biodiesel in lower percentage improved the engine performance and emission characteristics. This has again been agreed that 15% DEE with Karanja oil methyl ester blend is the effective combination. Pugazhvadivu et al. found that 15% to 20% of DEE addition was more beneficial in reducing NOx compared to 10% DEE by using the combination of Diesel, Pongamia biodiesel and diethyl ether as fuel . Use of metal based additive such as Mgo combined with oxygenated additive (Palm – polyol) was found reducing exhaust emissions especially for NOx from biodiesel, diesel blended fuel combustion. In this research, biodiesel has been prepared from the seeds of

* Corresponding author's e-mail:rameshbabu.p@gmrit.org

Thevetia peruviana plants called yellow oleander. Balusamy et al. found that the engine performance with the biodiesel of Thevetia puruviana was comparable to that of diesel. CO, HC emissions were less but NOx and smoke are slightly higher than that of diesel. Mohanan was found that 5% DEE-Diesel blend is the most effective combination based on performance and emission characteristics. .

Kapilan et al. conducted experiments with 5 % DEE and found lower CO, THC and smoke emissions while a slight improvement in thermal efficiency was observed. Yeh et al investigated the effect of fourteen different oxygenated fuels on diesel emissions, especially PM and NOx emissions. Annand et al also has achieved the simultaneous reduction of oxides of nitrogen (NOx) and smoke emissions by using 10 to 30% DEE by volume along with 5 to 15% EGR through an experimental investigation on a diesel engine. They found that 5% EGR operated with 20 vol. % of DEE–diesel blend to be favorable. Diethyl ether (DEE), which can be easily converted through ethanol, has high cetane number (approximates to 125) and could be used as a cetane improver. Meanwhile it is liquid at ambient condition, which makes it well handled.

The purpose of this investigation is to analyse the effect of DEE as a supplementary oxygenated fuel along with biodiesel MME on emission and performance of diesel engine to match the benefits of MME such as its lower HC, CO and smoke emissions and to decrease its NOx production (which increase in biodiesel fuelled engines). It is also desired to find out optimum amount of DEE to blend with MME based on performance and emission characteristics. In this research, DEE was added in the ratio of 5%, 10%, 15% and 20% to the MME.

2. Preparation and Characterization of Fuels (MME & DEE)

Transesterification is the general term used to describe the important class of organic reactions, where an ester is transformed into another ester through interchange of alkyl groups and is also called as alcoholysis. Transesterification is an equilibrium reaction and the transformation occurs by mixing the reactants. However, the presence of a catalyst accelerates considerably the adjustment of the equilibrium.

The general equation for transesterification reaction is given below.

RCOOR' + R" OH ↔ RCOOR" + R' OH ----------------Eq. (1)

The basic constituent of vegetable oils is triglyceride. Vegetable oils comprise of 90-98 percent triglycerides and small amounts of mono glyceride, di glyceride and free fatty acids. In the transesterification of vegetable oils, a triglyceride reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol. The overall process is a sequence of three consecutive and reversible reactions in which diglyceride and mono glycerides are formed as intermediates. The stoichiometric reaction requires one mole of triglyceride and three moles of alcohol. However, an excess of alcohol is used to increase the yield of alkyl esters and to allow phase separation from the glycerol formed.

Table1 Characterization of Diesel, DEE&MME

S.No.	Property	Diesel	MME	DEE (additive)
1	Viscosity (cSt)	2.75	4.25	0.23
2	Density(kg/m^3)	0.83	0.899	0.713
3	Cetane number	45	50	>125
4	Calorific Value (kJ/kg)	43000	36,700	33,900
5	Boiling point	180-360^{0}C	360^{0}C	35^{0}C
6	Auto ignition temperature	250^{0}C	>300^{0}C	160^{0}C

3. Experimentation

Due to lower density difference, blending is not difficult and also no separation observed. The additive is having higher Cetane value and lower density, lower auto ignition temperature and boiling point indicates that it starts ignition and initiates ignition of the main fuel i.e. biodiesel. The quantity of additive is limited to 15% of the main fuel is understood from the tail pipe emissions. 3% mixture of additive is going in consonance with the 15% additive similar in all aspects but there is a zone of equivalence ratio in which 15% additive plays important role in saving fuel and running the engine smooth as per the vibration signatures investigated. The additive prepares for better combustion of the main fuel because of its better combustion characteristics in advance and elevates the stature of combustion to higher strata to enhance the efficiency to better levels when compared to petro diesel.

The experimental setup consists of the following equipment

1. Single cylinder DI-diesel engine loaded with eddy current dynamometer
2. Engine Data Logger
3. Exhaust gas Analyzer
4. Smoke Analyzer
5. Vibration Analyzer

The Piezo electric transducer is fixed (flush in type) to the cylinder body (with water cooling adaptor) to record the pressure variations in the combustion chamber. Crank angle is measured using crank angle encoder. Exact TDC position is identified by the valve timing diagram and fixed with a sleek mark on the fly wheel and the same is used as a reference point for the encoder to with respect to which the signals of crank angle will be transmitted to the data logger.

Table 2 Details of the engine are given below

Rated Horse power:	5 hp (3.73 kW)
Rated Speed:	1500rpm
No of Strokes:	4
Mode of Injection and injection pressure	Direct Injection 200200 kg/cm^2
No of Cylinders:	1
Stroke	110 mm
Bore	80 mm
Compression ratio	16.5

The experimentation is conducted on the single cylinder direct injection diesel engine operated at normal room temperatures of 28^{0}C to 33^{0}C. The fuels used are diesel oil in neat condition and as well as methyl ester of Mahuva oil (MME) with 3%, 5%, 10%, and 15% additive Diethyl ether (DEE) and at five discrete part load conditions namely, No Load, One Fourth Full Load, Half Full Load, Three Fourth Full Load and Full Loads. The data collection is done independently for the above said oils. The engine is initially made to run at 1500rpm continuously for one hour in order to achieve the thermal equilibrium under operating conditions.

4. Results & discussions

4.1Engine Performance study

Biodiesel run engine maintains equivalence ratio of 7 at full load because the fuel consumption is more and also because of its lower heat value. In all other cases of additive blends, the equivalence ratio increases at full load. If compared 3% and 15% blends of DEE additive, 15% blend is more economical at part load performance of the engine approximately in between 0.4 and 0.65 equivalence ratios of the engine running it can be observed from the Fig 1. The brake specific fuel consumption increases from 0.3 kg/kW/hr to 0.375 kg/kW/hr when additive is being added with the defined blend percentages to the bio diesel. In the case of Neat biodiesel application, the BSFC stays at approximately 0.35 and with the additive percentages, it increases slightly, simultaneously increasing the equivalence ratio.

There is a steep rise of thermal efficiency for the additive percentages of '3' and '15' at part loads of the engine matching with the equivalence ratios 0.4 and 0.65 which can be observed from Fig 2. For the additive blend 15%, the thermal efficiency stays at approximately 27% at full load. This steep rise may be due to better Cetane number and lower boiling point temperature of the additive.

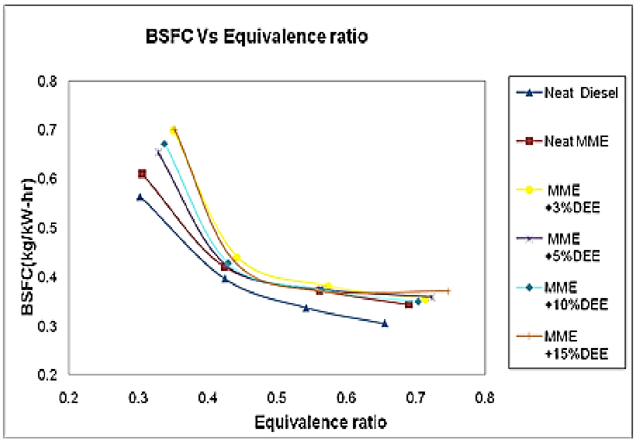

Fig.1 Brake Specific Fuel Consumption Vs Equivalence Ratio with different percentages of additive Diethyl Ether (DEE)

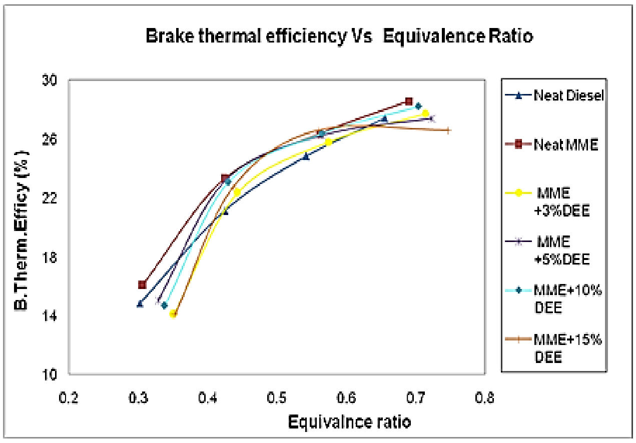

Fig. 2 Brake Thermal Efficiency Vs Equivalence Ratio with different percentages of additive Diethyl Ether (DEE)

4.2 Engine Emissions

Brake load of 40kg on the spring balance of the eddy current dynamometer is equivalent to full load on the engine.

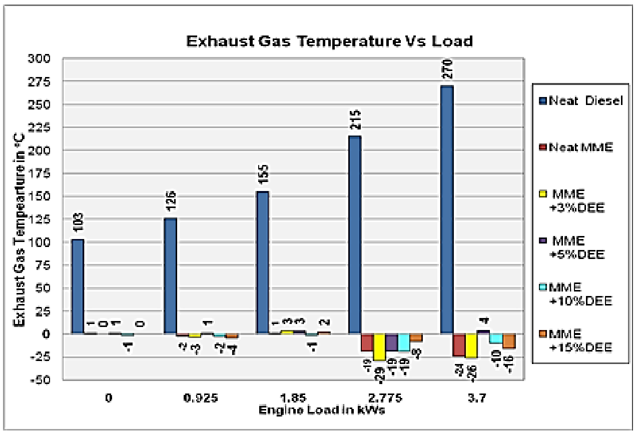

Fig.3 Exhaust Gas Temperature Vs Load with different percentages of (DEE) along with Biodiesel at all loads

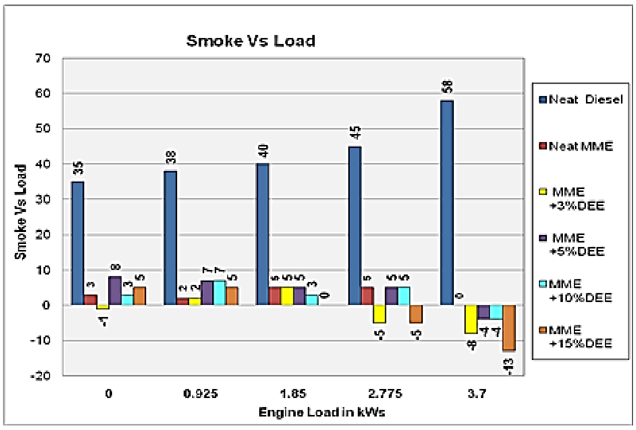

Fig.4 Smoke Vs Load with different percentages of (DEE) along with Biodiesel at all loads

Fig. 3 envisages higher exhaust gas temperatures with 15% additive than at 3% indicating better diffused combustion as explained in the previous paragraphs. Fig.4 gives the smoke emission plot in HSU at various loads and at various additive percentages. 15% f the DEE additive gives better smoke reduction indicating better combustion. Smoke emission showed minimum at all loads with 15% blend which made to rethink the suitability of 15% blend for practical use where the load variance of the engine lies at part loads to keep up the thermal efficiency

The plots from Figures (5) to (8) represent pillar graphs from no load to full load running condition of the engine with different fuel blends. These plots indicate comparison of various tail pipe gases viz. Carbon monoxide (CO), Hydrocarbons (HC), CO2 and Nitric Oxide (NO), respectively.

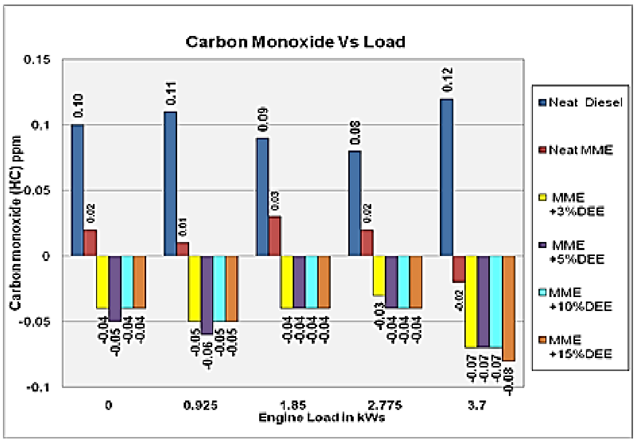

Fig. 5 Carbon monoxide Vs Load with different percentages of additive Diethyl Ether (DEE)

From the Fig. 5 it is observed that, there is 0.08% of CO emission difference at full load, the minimum happens to 15% DEE & Biodiesel blend and maximum for neat diesel. At part loads also the emission difference is also reasonable as can be observed from the Fig. 6 that 3% DEE blend in question is not standing superior to 15% blend as the emission quantities are lower.

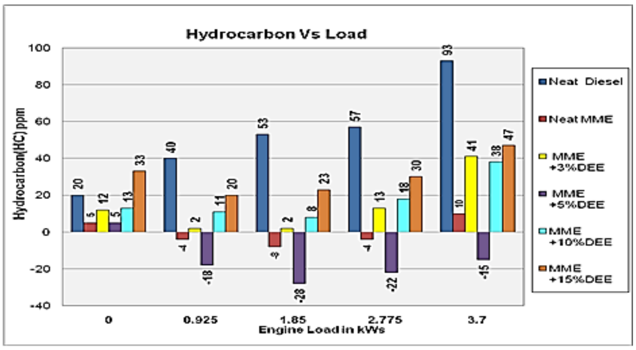

Fig. 6 Hydrocarbon Vs Load with different percentages of additive Diethyl Ether (DEE)

The unburned hydrocarbon (in ppm) emission is more in the case of additive blends and it is maximum with 15% blend. There is nearly 50 ppm of HC emission difference in between the fuels diesel and 15% DEE blend as shown in Fig. 6. With 5% additive blend the HC emission is the lowest of all at all loads but there is slight increase in CO correspondingly.

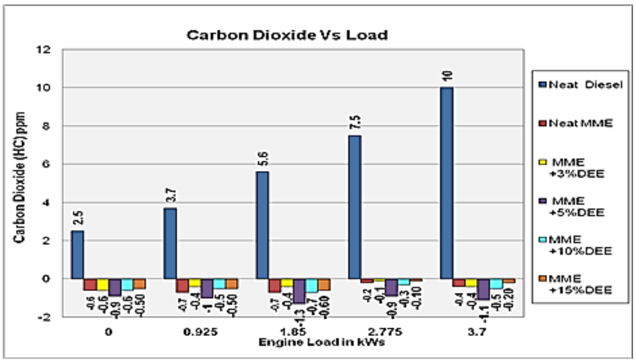

Fig. 7 Carbon dioxide Vs Load with different percentages of (DEE) along with Biodiesel at all loads.

It can be observed that there is nearly 50% reduction in CO emission with the application of blends and this makes beautiful advantage of the blends with DEE Even though the there is more oxygenated additive at 15%, contribution to NOx formation is less and there is contribution to the formation of CO2 as can be observed from the Fig.7

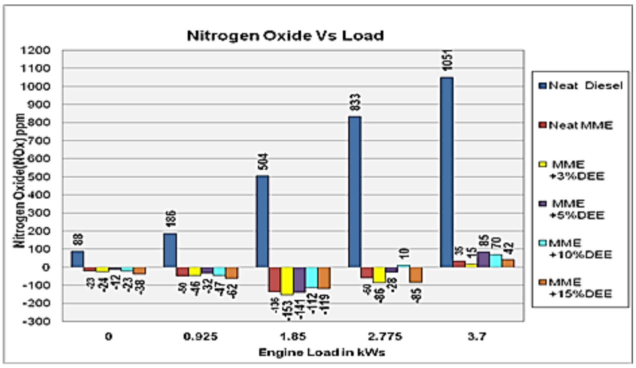

Fig. 8 Nitrogen oxide (NOx) Vs Load with different percentages of (DEE) along with Biodiesel at all loads.

As observed from Fig.8 there is rise in NOx emission at full load with additive and at part loads the emissions are low by margins of 62, 85and 85ppm at 1/4th ,1/2, and 3/4th full loads respectively and there is a reason to accept that the NOx emission reduction is insignificant with the blends because of higher molecular oxygen both in biodiesel and DEE. Lower loads mean lower combustion temperatures and hence lesser formation of NOx. Only one danger that can be anticipated is raise in the HC emission with respect to its percentage in the blend. 15% is the maximum limit of the blend proportion that has been preset here keeping in view the maximum emission of harmful HC.

Conclusions

- The additive DEE and the main biodiesel are possessing nearer densities and the blend 15 % is also observed to be stable during engine operation over limited hours observed in the laboratory and is adjudged as the best combination which yielded better results than other fuel blends tested.
- The thermal efficiency rise and SFC are better in the case of 15% additive blend and since diesel engines give better efficiency at part loads this percentage of blend can be recommended.
- The equivalence ratio at full load in the case of the two blends differ marginally, 15% blend can be adopted for the reason the difference is significantly small and there won't be much larger loss of fuel at little higher equivalence ratio.
- The smoke levels have decreased substantially with 15% DEE blend with biodiesel at full load and at immediate part load except very low loads at which the diesel engine may not be put to operation normally because of high bsfc. Smoke levels have decreased in tandem indicating better combustion.
- Better dilution with higher percentages of additive yielded better results but as the dope percentage is increasing, the emission of unburned hydrocarbons (HC) keep on increasing.15% additive reached highest HC release accepted by pollution norms.
- There is NO reduction at part loads in the case of additives .But at full load the NO emission has increased due to excessive molecular oxygen in both additive and biodiesel.
- There is slight increase in CO emission with respect to additive percentage. But when compared to diesel and biodiesel operation there is substantial reduction up to 0.07% in general with the injection of blends. There is approximately 67% reduction in the CO emission with 15% DEE -biodiesel blend at full load running of the engine.
- 15% DEE blend is proved to be more compatible blend when compared to other blends tested in view of the all-round performance exhibited by the additive.

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