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

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Abstract

An experimental Investigation is carried out to study the performance and emission on Laboratory based direct injection, diesel engine fueled with Bio diesel (PaME), Diesel and DEE blended fuel taking pure Diesel as base line. The test fuels are pure Diesel, pure PaME, (95% PaME + 5% DEE in vol.), (80% Diesel+15% PaME+5% DEE in vol.), (95% Diesel + 5% DEE in vol.), and (80% PaME +15% Diesel +5% DEE in vol.) respectively. The experiment has been conducted at fixed engine speed of 1500 rpm and at compression ratio of 18.5. Engine tests have been conducted to get the comparative measures of Specific Fuel Consumption (SFC), Brake thermal efficiency (BTh) and emissions such as CO, CO_2, HC, NO and NO_X to evaluate the behavior of PaME, Diesel and DEE blends in varying proportions. A marked improvement in the trade-off between NOx and smoke was achieved maintaining a high thermal efficiency by a suitable combination between the parameters mentioned above for each engine load. The results with the combination 80% Diesel+15% PaME+5% DEE in vol. were found encouraging in all respects of performance and improved emission characteristics.

Keyword - *biodiesel, Palm Methyl Ester, diethyl ether, performance.*

1. INTRODUCTION

Biofuels such as alcohols and biodiesel have been proposed as alternatives for internal combustion engines. In particular, biodiesel has received wide attention as a replacement for petro diesel fuel because it is biodegradable, nontoxic and can significantly reduce exhaust emissions and overall life cycle emission of carbon oxides (CO_2) from the engine when burned as a fuel. Many investigations have shown that using biodiesel in diesel engines can reduce hydro carbon (HC), carbon monoxide (CO) and particulate matter (PM) emissions, but nitrogen oxide (NOx) emission may increase [1-4]. The oxygen content of biodiesel is an important factor in the NOx formation, because it causes to high local temperatures due to excess hydrocarbon oxidation. The increased oxygen levels increase the maximum temperature during the combustion, and increase NOx formation [5,6]. Due to having the higher cetane number which causing shorter ignition delay and hence lower temperatures during the pre combustion phase. On the other hand, biodiesel has some disadvantages, such as higher viscosity and pour point, and lower volatility compared with diesel. The poor cold flow property of biodiesel is a barrier to the use of biodiesel-diesel blends in cold weather [7]. Diethyl ether might be expected to improve low temperature flow properties.

Previous studies have suggested that the weight percent of oxygen content in the fuel is the most important factor for Particulate Matter reduction, and it is more important than other properties such as chemical structure or volatility [8, 9]. Including diethyl ether and biodiesel and diesel blends can increase the oxygen contents, which may further improve the PM emissions. Investigations have been carried out on different approaches for improving exhaust emission when biodiesel is used. Prommes et al. [11] studied the phase diagram of diesel-biodiesel-ethanol blends at different purities of ethanol and different temperatures, examined the fuel properties of the selected blends and their emissions performance in a diesel engine and compared to those of base diesel. They concluded that a blend of 80% diesel, 15% biodiesel and 5% ethanol was the most suitable ratio because of the acceptable fuel properties and the reduction of emissions. Constantine Zannis et-al [12] observed that decrease of ignition delay with increasing oxygen content, following thus the increase of cetane number. A considerable reduction of soot, carbon monoxide and unburned hydrocarbon emissions were witnessed while nitric monoxide emissions increased when the oxygen content increased from 3% to 9% by the addition of oxygenated additives. Oxygenated additives have been considered for reducing the ignition temperature of particulates. However, the reduction of particulate emissions through the introduction of oxygenated compounds depends on the molecular structure and oxygen content of the fuel and also depends on the local oxygen concentration in the fuel plume [13]. To reduce particulate emissions, fuel-compatible oxygen-bearing compounds should be blended with diesel to produce a composite fuel containing 10-25% v/v of oxygenate. T.K.Kannan et al. [14] studied an oxygenated additive diethyl ether (DEE) was blended with bio diesel in the ratios of 5%, 10%, 15% and 20% and tested their performance. Reduction of 14.63% of smoke opacity and 15% of NOx emission, was observed for 20% DEE blends at full load which was the highest reduction among the blends. BTE 29.9% which was 5% higher than biodiesel . M. Pugazhvadivu et al [15] studied the effect of adding DEE to biodiesel-diesel blends (B25, B50 and B75) and biodiesel (B100) . DEE was added in 10%, 15% and 20% (v/v) to the biodiesel fuels. This revealed addition of diethyl ether to biodiesel blends reduced the both NO_X and smoke emission further.

In this Investigation and study, we investigate the engine performance and emissions characteristics with fuel blends of petro diesel, biodiesel PaME), and diethyl ether (DEE) on a diesel engine. The specific fuel consumption (SFC), break thermal efficiency, emissions are investigated and studied.

2. EQUIPMENT AND EXPERIMENTS

A .Experimental Fuels

The Petro diesel fuel employed in the tests is obtained from nearest filling station. The biodiesel produced from Palm oil is prepared by a method of alkaline-catalyzed transesterification. The lower calorific value of biodiesel is approximately 8% lower than that of diesel. The viscosity of biodiesel is evidently higher than the petro diesel. In the experimental study, four fuels are prepared taking diesel as baseline fuel, pure PaME, (95% PaME + 5% DEE in vol.), (80% Diesel+15% PaME+5% DEE in vol.), (95% Diesel + 5% DEE in vol.), and (80% PaME +15% Diesel +5% DEE in vol.) transesterification of Palm oil was carried out by heating of oil, addition of KOH and methyl alcohol, stirring of mixture, separation of glycerol, washing with distilled water and heating for removal of water. The PaME so produced was mixed with diesel in varying proportions diesel and diethyl ether with the help of a magnetic stirrer above said combinations. The blends were stirred continuously to achieve stable property values. Fuel properties such as flash point, fire point, kinematic viscosity and calorific value were determined for PaME and DEE and are compared with the diesel.

Properties	**Diesel**	**Biodiesel (PaME)**	**DEE**
Density(kg/m2)	850	916	713.4
Kinematic viscosity at 40oc(Cst)	3.05	5.8	0.2230
Calorific value (kj/kg)	42800	39400	33892
Cetane number	47	50	85-89
Flash point ◦C	85	129	-45
Surface tension N/m at 20°C	0.023	0.025	0.017
Latent heat of Evaporation kJ/kg	250	240	376
Molecular weight	170	200	74.12
Stoichiometric air to fuel ratio Wt/wt	15	13.5	11.1
Auto ignition temperature ◦C	316	-	160
Boiling point ◦C	188-344	-	34
Carbon content % weight	84-87	-	64.86
Hydrogen content % weight	33-16	-	13.5
Oxygen content (%) weight	0	10	21

Table 2.1 Properties of Diesel, PaME and DEE

B. Experimental setup and Procedure

The experimental set up consists of a single cylinder four-stroke, water-cooled and constant-speed (1500 rpm) compression ignition engine. The detailed specification of the engine is given below.

Product	Research Engine test setup 1 cylinder, 4 stroke, Multifuel, VCR, Code 240
Engine	Single cylinder, 4 stroke, water cooled, stroke 110 mm, bore 87.5 mm, 661 cc. Diesel mode: 3.5 KW, 1500 rpm, CR range 12-18. Injection variation:0-250 BTDC Petrol mode: 4.5 KW@ 1800 rpm, Speed range 1200-1800 rpm, CR range 6-10,
Dynamometer	Type eddy current, water cooled, with loading unit
Fuel tank	Capacity 15 lit, Type: Duel compartment, with fuel metering pipe of glass
Calorimeter	Type Pipe in pipe
ECU	PE3 Series ECU, Model PE3-8400P, full build, potted enclosure. Includes peMonitor & peViewer software.
Piezo sensor	Combustion: Range 350Bar, Diesel line: Range 350 Bar, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	Type two wire, Input RTD PT100, Range 0–100 Deg C, Output 4–20 mA and Type two wire, Input Thermocouple,
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	“Enginesoft” Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Overall	W 2000 x D 2500 x H

dimensions	1500 mm

Table 2.2 Test Engine Specification

C. Specification of diesel engine

The setup consists of single cylinder, four stroke, Research engine connected to eddy current dynamometer. It is provided with necessary instruments for combustion pressure, crank-angle, airflow, fuel flow, temperatures and load measurements. These signals are interfaced to computer through high speed data acquisition device. The set up which is shown in Figs. (2.1-2.4) has stand-alone panel box consisting of air box, twin fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and piezo powering unit. Rota meters are provided for cooling water and calorimeter water flow measurement. In petrol mode engine works with programmable Open ECU, Throttle position sensor (TPS), fuel pump, ignition coil, fuel spray nozzle, trigger sensor etc The setup enables study of engine performance for both Diesel and Petrol mode and study of ECU programming. Engine performance study includes brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, Air fuel ratio, heat balance and combustion analysis. A series of experiments were carried out using diesel, biodiesel and the various blends with DEE. All the blends (Test fuels) were tested under varying load conditions (no load to the rated maximum load) using eddy current dynamometer which is shown in Fig.2.5. at the constant speed. During each trial, the engine was started and after it attains stable condition, important parameters related to thermal performance of the engine including the time taken for 20 cm^3 of fuel consumption, applied load, the ammeter and voltmeter readings were measured and recorded. Also, the engine emission parameters like CO, CO_2, NO, NOx, and oxygen from the exhaust gas analyzer, which is shown in Fig.2.6 were noted and recorded.


Fig.2.1.Test Engine for this work

Fig.2.2.Digital data for engine speed


Fig.2.3.Computerised data logging system

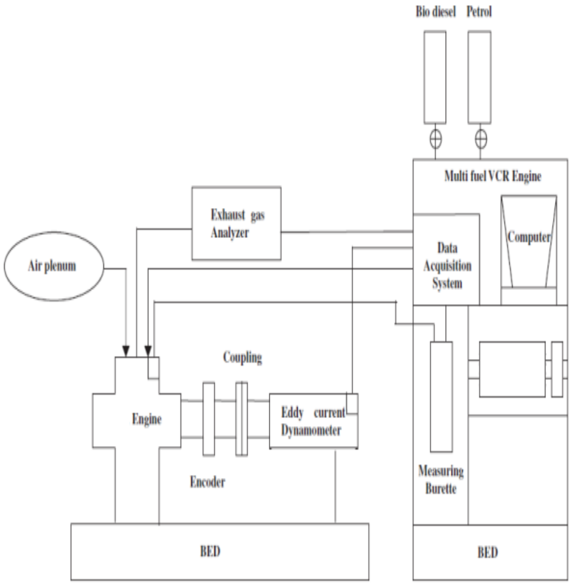

Fig.2.4. Line diagram for experimental set up

Fig.2.5. Eddy current dynamometer for loading

Fig.2.6.Exaust gas analyzer

3. RESULTS AND DISCUSSIONS

A. Thermal Efficiency and Specific Fuel Consumption

The variation of brake thermal efficiency for different compositions increased with increase in load due to reduction in heat loss and increase in power. The variation of brake thermal efficiency with load for different combination of blends has been plotted and it is shown in Fig 3.1. In all cases, increment with load is present except fuel combination 95% PaME+5%DEE at full load due to lack of volumetric efficiency. The maximum thermal efficiency for fuel combination 80% Diesel+15% PaME+5% DEE in vol., (28.96 %) was higher than that of diesel [26.14%].This happens due to the addition of oxygenated fuel combination with PaME and DEE. The brake thermal efficiency obtained for other fuel combinations mainly with PaME and DEE combinations were less than that of Petro diesel. This lower brake thermal efficiency obtained could be due to reduction in calorific value and increase in fuel consumption as compared to fuel combination 80% Diesel+15% PaME+5% DEE in vol. Hence, this combination of fuel blend was selected as optimum blend for further investigations and long-term operation. Based on the results it can be concluded that the performance of the engine with above said fuel combination is comparable to that with pure diesel.

The variation of SFC with load for different blends and diesel are presented in Fig 3.2. It is observed that the SFC for all the combination of fuel blends and diesel decrease with increase in load. For fuel combination 80% Diesel+15% PaME+5% DEE in vol. blend, the SFC is lower than diesel for all loads starting from no load by 88% to 75% at full load. For DEE addition to diesel and Bio diesel the SFC is almost same as that of diesel at full load. Hence it is concluded that the fuel is completely burnt at the right time in the engine cylinder. This could be due to the presence of dissolved oxygen in the biodiesel and DEE that enables complete combustion. However as the biodiesel concentration in the blend increases further, the SFC increase for all loads and the percentage increase are higher at low loads. This could be due to the specific gravity of biodiesel is more than diesel and high mass flow of fuel entering into the engine.

B. Emission analysis

CO emission

It is interesting to observe that the engine emits more CO for diesel as compared to biodiesel and other fuel combination blends at lower loads except (80% Diesel+15% PaME+5% DEE in vol.), this is happened due to complete combustion inside the cylinder. It is seen from the Fig 3.3., that the CO concentration is totally absent for the above mentioned fuel combination for all loading conditions and as the DEE addition in the pure diesel and pure PaME increases CO is observed. But the fuel with the combination 80% Diesel+15% PaME+5% DEE in vol., presents lower CO emission at all load conditions due to biodiesel and DEE concentration, the oxygen present in them aids for complete combustion.

CO_2 emission

Fig 3.4. Depicts the CO_2 emission of various fuels combinations used. The CO_2 emission increased with increase in load for all blended combinations except at full load. The pure biodiesel and its blend with DEE (95% PaME) produce lower concentration of CO_2 at lower loads but DEE addition increases. The fuel with the combination 80% Diesel+15% PaME+5% DEE in vol., presents lower CO_2 emission at all load conditions and emit very low emissions. This is due to the fact that biodiesel is a low carbon fuel and has a lower elemental carbon to hydrogen ratio than diesel fuel.

NO emission

The NO emission variation for different combination of blends is indicated in Fig 3.6. It is seen that the NO emission increases with increase in load for all test fuels for 95% Biodiesel and DEE has higher NO emission at higher loads than the lower loads. As the Cetane number of ester based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion leading to low NO emission but when it's blend with DEE produces more NO emission.

NOx emission

The variation of NOx emission for different blends is indicated in Fig 3.5. The NOx emission for all the fuels tested followed an increasing trend with respect to load except the fuel combination 80% Diesel+15% PaME+5% DEE in vol. The reason could be the higher average gas temperature, residence time at higher load conditions. An increment in the emission for all the blends as compared to diesel was noted. With the DEE content of the fuel, corresponding increment in emission was noted and the reduction was remarkable for the above said fuel combination. The maximum and minimum amount of NOx produced were 112 ppm and 13 ppm corresponding to that.

C. Combustion performance

Combustion pressure curves are obtained at all fuels which are used for experimentation at five defined loads .It can be observed earlier start of combustion in the case of neat palm methyl ester when compared to the Petro-diesel burning. Blending is delaying the start of combustion to bring it back to the status of diesel combustion. Visibly, there is sharp shoot up of combustion pressure in the case of DEE addition in the last three loads. Better diffused combustion and pronounced hump is observed in the net heat release rate curves [Fig.3.7]. It can be observed from the full load curves of any combination of blended fuel combustion, the combustion is spread over wider range of crank angle and the net heat release rate curves also indicate better diffused combustion. There is clear cut fall in the pressure development since the pressure shoot up is step at the beginning and then drops to lower level and regains over comparatively wide range of crank angle.

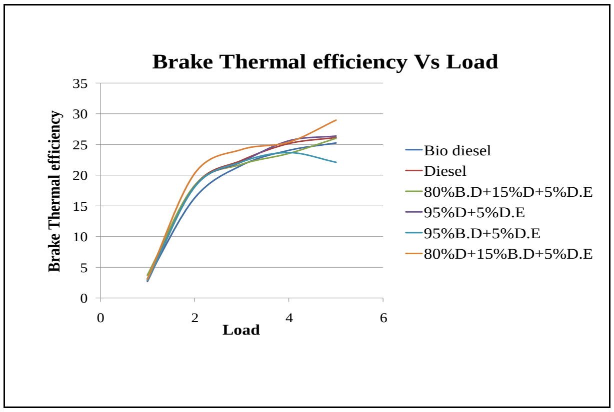

Fig.3.1 Brake Thermal efficiency Vs Load

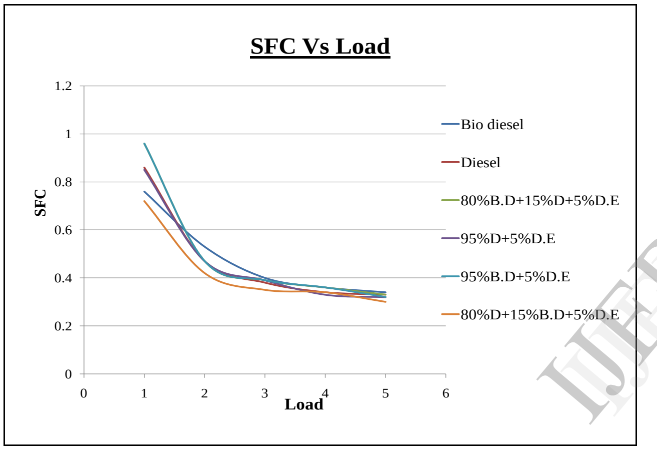

Fig.3.2 Specific fuel consumption Vs Load

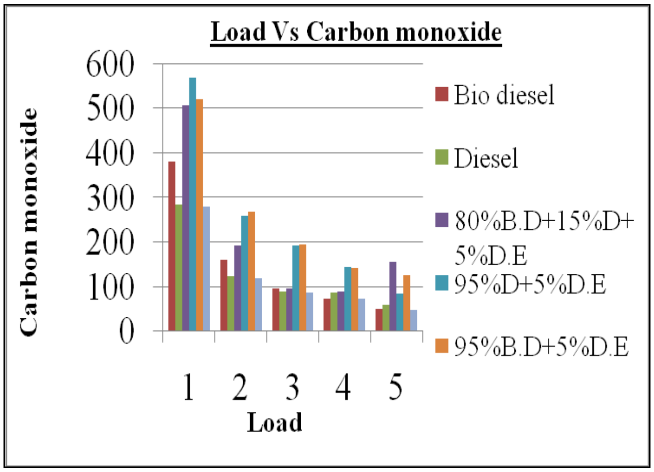

Fig.3.3. Load Vs Carbon monoxide

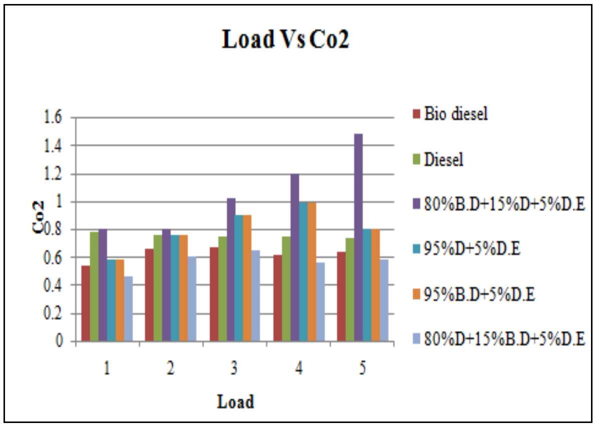

Fig.3.4. Load Vs Co$_2$

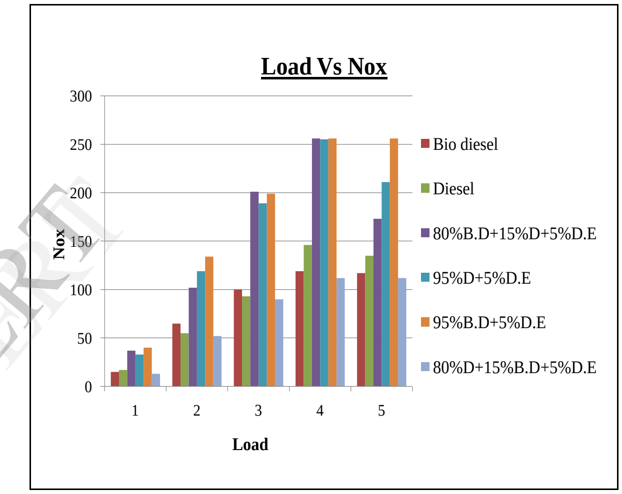

Fig.3.5. Load Vs Nox

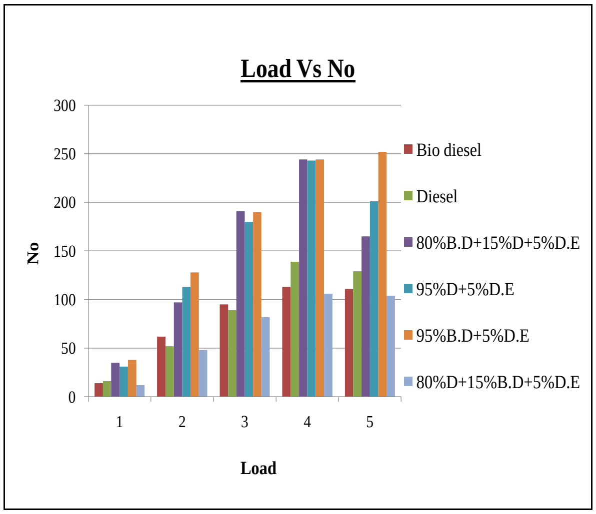

Fig.3.6. Load Vs No

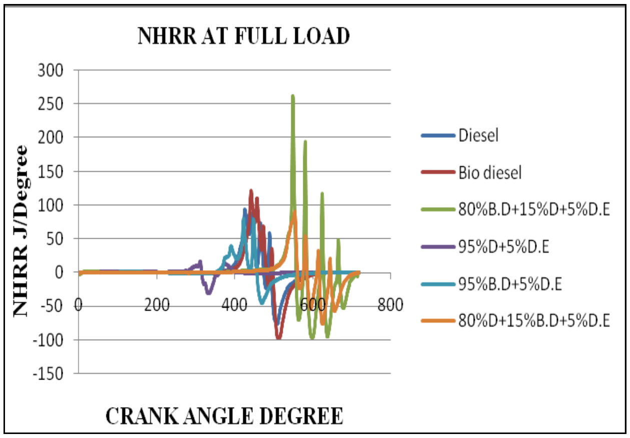

Fig.3.7. NHRR at Full Load

4. CONCLUSIONS

The experimentally investigated the addition of diethyl ether on engine performance and emissions of a biodiesel(PaME),diesel and Diethyl ether blended fuel engine. Diesel, Biodiesel and diethyl ether blend i.e. 80% Diesel+15% PaME+5% DEE in vol., show better stability and can be used in diesel engine without any modification. The SFC and BTE are in the way of encouraging due to having higher oxygen content than pure diesel and pure biodiesel, show excellent ability to eliminate smoke emissions, especially at high engine load due to Diethyl ether has higher volatility.

Prediction for CO, CO_2, NO, NOx emissions will drastically decreased when 80% Diesel+15% PaME+5% DEE in vol., is used. Oxygen content also improved and better diffused combustion and pronounced hump is observed.

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