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Performance and Emission Study on DI-CI engine run with Blended Fuel of Biodiesel (PME) – Diesel

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Abstract

An experimental study is carried out to investigate the performance and emission on direct injection, compression ignition engine (Laboratory based engine) run with Bio diesel (PME) –Diesel blended fuel taking pure Diesel as base line. The test fuels are B100 (pure Biodiesel), B 80 (80% PME – 20% Diesel in vol.), B50 (50% PME – 50% Diesel in vol.), B20 (20% PME – 80% Diesel in vol.) and pure Diesel 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, CO2, HC, and NOX to evaluate the behavior of PME and Diesel in varying proportions. The results with the combination 50% PME – 50% Diesel in vol. (B50) were found encouraging in all respects of performance and improved emission characteristics.

Keywords:*Biodiesel; Pongamia methyl ester; Hydrocarbon; Exhaust emission*

1. Introduction

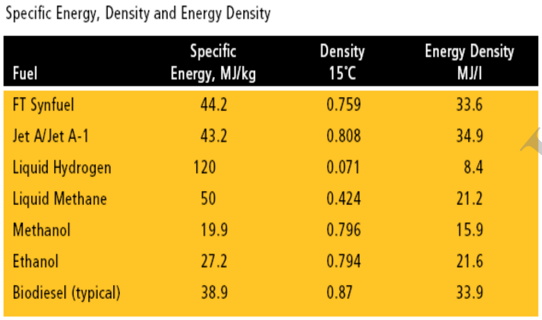
Petroleum products have always been the preferred transportation fuels because they offer the best combination of energy content, performance, availability, ease of handling and price. Besides price, other factors must be taken into account when considering bio fuels. Bio fuel, biodiesel have been proposed as alternatives for internal combustion engines. In particular, biodiesel has received wide attention as a replacement for diesel fuel because it is biodegradable, nontoxic and can significantly reduce exhaust emissions and overall life cycle emission of carbon oxides (CO2) from the engine when burned as a fuel. Many investigations from researchers have shown that using biodiesel in diesel engines can reduce hydrocarbon (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]. Although the little higher cetane number (shorter ignition delay and so lower temperatures during the premixed combustion phase) and the absence of aromatics tend to contribute to less NOx production, these factors do not seem to offset the increase caused by the presence of the fuel-bound oxygen even in locally rich zones . 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].

Of course, safe and reliable operation of the engine must be considered. There are two important factors that are to be considered. One is the price of petro fuel well beyond the prices of bio fuels and the second being the best use of vegetable oil fuels. Biodiesel for automobile use has already taken place in many courtiers to reduce the problem. Several methods like Blends, emulsified fuel and dual fuel. Higher HC emissions were reported in the studies presented in the cases described above. 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.

Petroleum products have always been the preferred transportation fuels because they offer the best combination of energy content, performance, availability, ease of handling and price. However, the recent increase in the price of oil has prompted the industry to look at alternative fuels. National concerns about energy security, continuous availability of petroleum, the “peak oil” debate, are all important issues [8]. Other than price, when it is being talked about alternative fuels, the factors we must take into consideration are, safe and reliable operations of the engine, environmental effects, emissions from the engine and also Life-cycle effects associated with the production and use of an alternative fuel.

Alternative fuels for aviation have been considered since the early days of turbine engines. Cryogenic fuels such as liquid hydrogen and other more exotic fuels such as boron compounds were studied in the 1950s and 1960s[9]. Research into alternative fuels was conducted after the 1973 U.S. energy crisis when fuel prices increased dramatically. A lot of work and research was done at that time on biomass conversion to fuel [10, 11]. However, only petroleum-derived jet fuels have been found to be economically practical for widespread, routine use.

Some potential alternative fuels, like alcohols and esters contain oxygen. These fuels have lower energy content because the oxygen in the fuel molecule doesn't contribute any energy during combustion. Energy is released by breaking carbon-carbon and carbon-hydrogen bonds in hydrocarbons and converting them to carbon-oxygen and hydrogen-oxygen bonds. The oxygen needed for combustion is both from air and oxygen alreadycarried in the fuel molecule. As a result, these fuels have lower energy content than hydrocarbon fuels.The properties and mass of the fuel and volume per unit energy have been tabulated in the [tables 1.1].



Specific Energy, Density and Energy Density

Fuel	Specific Energy, MJ/kg	Density 15°C	Energy Density MJ/l
FT Synfuel	44.2	0.759	33.6
Jet A/Jet A-1	43.2	0.808	34.9
Liquid Hydrogen	120	0.071	8.4
Liquid Methane	50	0.424	21.2
Methanol	19.9	0.796	15.9
Ethanol	27.2	0.794	21.6
Biodiesel (typical)	38.9	0.87	33.9

Table.1.1. Energy properties of different fuels

The use of biodiesel for diesel engine applications is studied by various researchers. Some of the recent studies which dealt with transesterification, performance study and emission analysis are reported. Demirbas [12] reviewed the bio-diesel production, characteristics and the experimental works carried out in the field of bio-diesel. It is reported that the transesterification of triglycerides by methanol, ethanol, propanol and butanol has proved to be the most promising process. Also molar ratio of alcohol to vegetable oil and reaction temperature, catalyst, pressure, reaction time and the contents of the free fatty acids and water in oils are the variables affecting the methyl ester yield during the transesterification reaction. It is also reported that in the supercritical methanol transesterification method, the yield of conversion raises 96% in 10 min. Karmee and Chala [13], prepared biodiesel from Pongamiapinnata by transesterification of the crude oil with methanol and KOH as the catalyst and reported a 92% conversion at 60 1C with 1:10M ratio for KOH and the properties such as viscosity, flash point of the bio-diesel compare well with accepted standards. Burnwal and Sharma [14] reviewed the work done on biodiesel production and utilization, resources available, processes developed/being developed, engine performance, environmental considerations, economic aspects, advantages and barriers to the use of biodiesel. It isreported that triglycerides (vegetable oils/animal fats) hold promise as alternate fuels in diesel engines and the methods for improvement in fuel properties are catalytic transesterification of triglycerides with alcohols to form mono alkyl esters of long chain fatty acids and the supercritical method of producing bio-diesel, which is quite similar to hydrocarbon based diesel fuels. Kumar et al. [15] have tested a constant speed diesel engine with Jatropha oil methyl ester and reported a higher ignition delay as compared to that of diesel.

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 PongamiaPinnata is prepared by a method of alkaline-catalyzedtransesterification. The lower calorific value of biodiesel is approximately 7% lower than that of diesel. The viscosity of biodiesel is evidently higher than the diesel. In the experimental study, four fuels are prepared taking diesel as baseline fuel, B 100 (neat PME), B 20 (20% PME + 80% Diesel in vol), B 50 (50% PME + 50% Diesel in vol), B 80 (80% PME + 20% Diesel in vol). Transesterification of Pongamia 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 PME so produced was mixed with diesel in varying proportions from 20% to 100% by volume (B20, B50, B80, and B100) with the help of a magnetic stirrer. 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 PME and are compared with the diesel.

S.No	Name of the oil sample → ↓Characteristics	Diesel	Pongamia Methyl Ester (PME)
1	Density at 310C (kg/m3)	833	873
2	Gross Calorific Value, (kJ/kg)	43000	38,800
3	Viscosity at 31cC, (cSt.)	2.78	4.56
4	Cetane Number	45-55	50
5	Rams bottom Carbon Residue,Wt%	0.1	0.36
6	Flash Point, oC	50	170
7	Pour Point, oC	Winter 3 Max, Summer 15 Max	< -3
8	Acid Number, mg KOH/gm	0.2 Max	< 0.2

Table 1.2 Properties of Diesel and Pongamia Methyl Ester.

B. Experimental setup andProcedure

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
Propeller shaft	With universal joints
Air box	M S fabricated with orifice meter and manometer
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
Pump	Type Monoblock
Overall dimensions	W 2000 x D 2500 x H 1500 mm

Table 1.3 Specifications of diesel engine.

Specification of diesel engine

The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) 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 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. Rotameters 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 VCR 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. All the blends were tested under varying load conditions (no load to the rated maximum load) using eddy current dynamometer which is shown in Fig .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 cm3 of fuel consumption, applied load, the ammeter and voltmeter readings were measured and recorded. Also, the engine emission parameters like CO, CO_2, HC, NOx, and the exhaust gas temperature from the exhaust gas analyser, which is shown in Fig.6 were noted and recorded.

Fig.1.Test Engine for this work

Fig.2.Digital data for engine speed

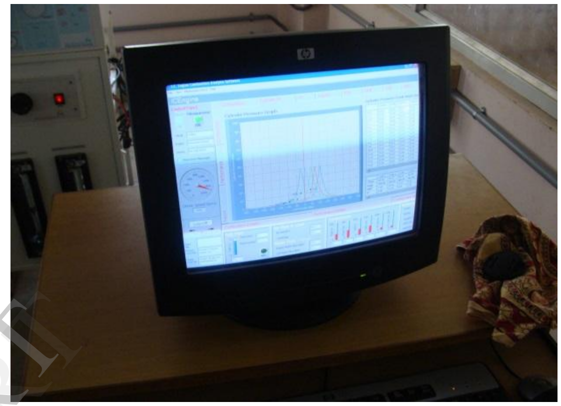


Fig.3.Computerised data logging system

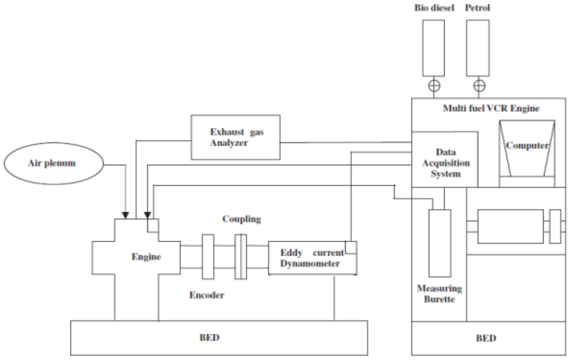


Fig.4. Line diagram for total experimental set up

Fig.5. Eddy current dynamometer for loading

Fig.6.Exaust gas analyzer

3.RESULTS AND DISCUSSIONS

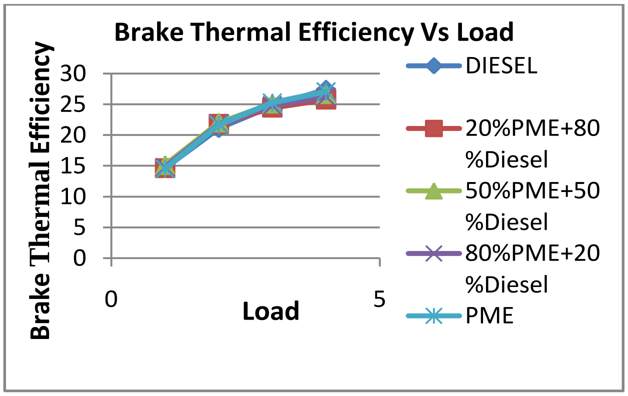


Fig.7. Brake Thermal Efficiency Vs Load

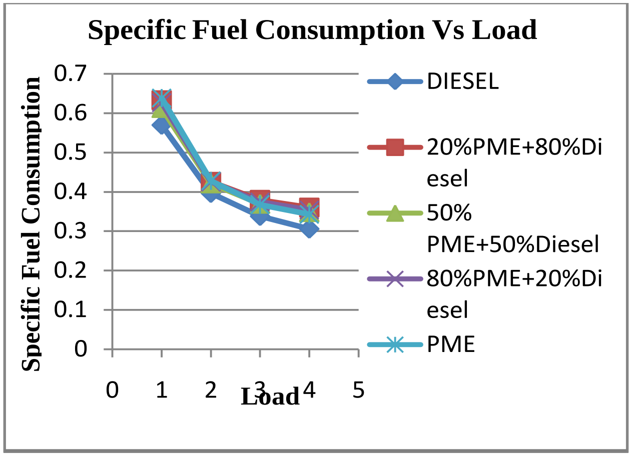


Fig.8. Specific fuel consumption Vs Load

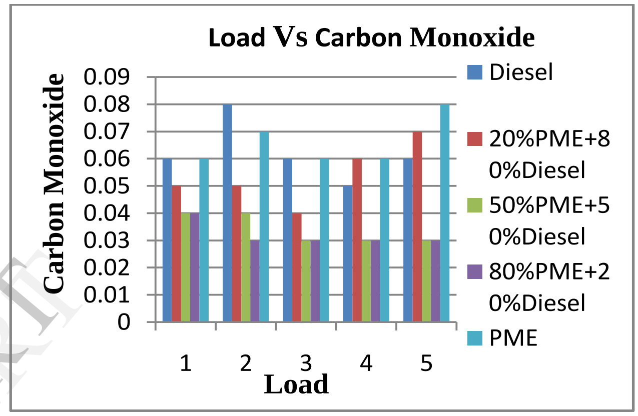


Fig.9. Load Vscarbon monoxide

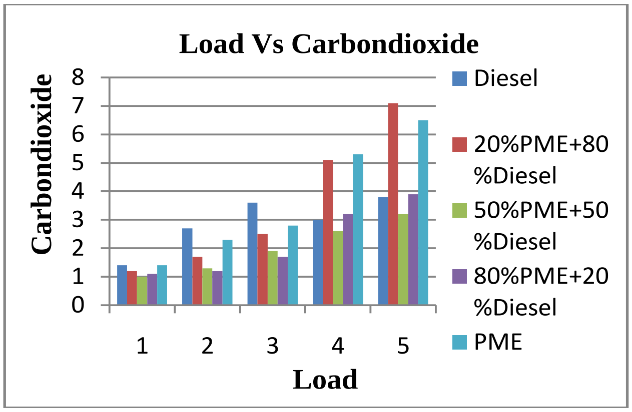


Fig.10. Load VsCarbondioxide

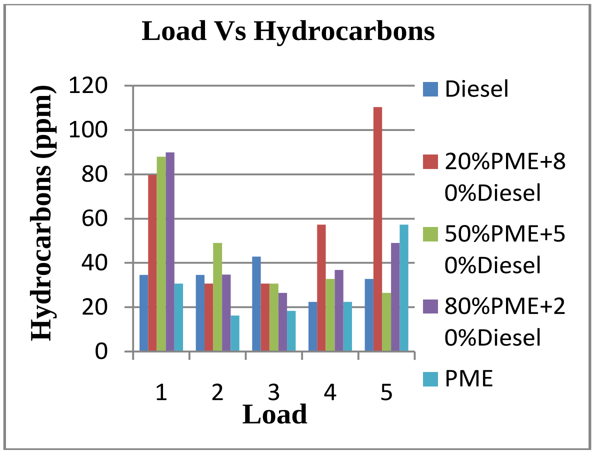


Fig.11.Load Vs Hydrocarbons

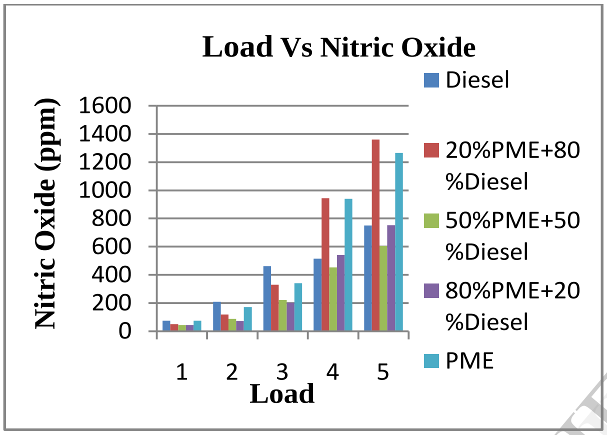


Fig.12. Load Vs Nitric Oxide

3.1. Brake Thermal Efficiency

The variation of brake thermal efficiency for different compositions increased with increase in load due to reductuion in heat loss and increase in power. The variation of brake thermal efficiency with load for different blends has been plotted and it is shown inFig 7. In all cases, increment with load is present. The maximum thermal efficiency for B50 (27.4 %) was nearer and slightly higher than that of diesel [27.38%]. The brake thermal efficiency obtained for B20, B80 and B100 were less than that of diesel. This lower brake thermal efficiency obtained could be due to reduction in calorific value and increase in fuel consumption as compared to B50. Hence, this 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 biodiesel blends is comparable to that with diesel.

3.2 Specific fuel consumption

The variation of SFC with load for different blends and diesel are presented in Fig 8. It is observed that the SFC for all the fuel blends and diesel tested decrease with increase in load. For B20 blend the SFC is lower than diesel for all loads. For B50, the SFC is almost same as that of diesel. 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 that enables complete combustion and the negative effect of increased viscosity would not have been initiated. However as the biodiesel concentration in the blend increases further, the SFC increase for all loads and the percentage increase is higher at low loads. This could be due to the high mass flow of fuel entering into the engine (specific gravity of biodiesel is 6% more than diesel).

3.3 CO emission

It is interesting to note that the engine emits more CO for diesel as compared to biodiesel blends at lower loads. It is seen from the Fig 9. that the CO concentration is totally absent for the blends of B50, B80 for all loading conditions and as the biodiesel concentration in the blend increases above 50%, the presence of CO is observed. At lower biodiesel concentration, the oxygen present in the biodiesel aids for complete combustion. However as the biodiesel concentration increases, the negative effect due to high viscosity and small increase in specific gravity suppresses the complete combustion process, which produces small amount of CO.

CO_2 emission

Fig 10.depicts the CO_2 emission of various fuels used. The CO_2 emission increased with increase in load for all blends. The lower percentage of biodiesel blends emits high amount of CO_2 in comparison with diesel. Blends B50 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 thandiesel fuel. Though at higher loads, higher biodiesel content blends emit CO_2 almost at par with diesel, biodiesels themselves are considered carbon neutral because, all the CO_2 released during combustion had been sequestered from the atmosphere for the growth of the vegetable oil crops.

HC emission

The HC emission variation for different blends is indicated in Fig 11. It is seen that the HC emission initially decreases and increases with increase in load for all test fuels for B50 higher HC emission at lower loads than the higher 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 HC emission. Also the intrinsic oxygen contained by the biodiesel was responsible for the reduction in HC emission.

NO_x emission

The variation of NO_x emission for different blends is indicated in Fig 12. The NO_x emission for all the fuels tested followed an increasing trend with respect to load. The reason could be the higher average gas temperature, residence time at higher load conditions. A reduction in the emission for all the blends as compared to diesel was noted. With increase in the biodiesel content of the fuel, corresponding reduction in emission was noted and the reduction was remarkable for B50. The maximum and minimum amount of NO_x produced were 600 ppm and 44 ppm corresponding to B50.

Conclusions

The main aim of the present study was to analyze the usability of PME as a replacement to diesel in an unmodified CI engine. It was proved that blends of PME and diesel can be successfully run with acceptable performance and emissions than pure petro diesel up to a certain extent. From the experimental investigation, it is concluded that blends of PME with diesel up to 50% by volume (B50) can replace the diesel for diesel engine applications for better emissions and improved performance. Biodiesel is having biodegradability and nontoxic nature which will help in achieving energy economy, environmental protection and rural economic development. In the near future conventional fuels like Diesel will be fully replaced by biodiesel and will provide a viable solution for the much threatening energy crisis and environmental pollution problems.

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