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Experimental Analysis of a VCR Engine Performance Using Neem Methyl Ester and its Diesel Blends

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***Abstract*: Bio diesel is an alternative fuel which is produced from edible or non-edible vegetable oil or animal fat. It is a best renewable substitute of conventional fuel. As a replacement of petroleum fuel it is much cleaner alternative. Its physical components are similar to regular diesel fuel. Experimental analysis of variable compression diesel engine performance and emission using Neem Methyl Ester Bio diesel (NeME),and pure Diesel at various load conditions at fixed compression ratio 17.5:1 to compare the result at each compression ratio considering pure diesel as base line. The experiment has been conducted at fixed engine speed of 1500 rpm and engine tests have been conducted to get the comparative measures of Specific Fuel Consumption (SFC), Brake thermal efficiency(BTh) and emission such as CO, CO_2, HC, and improved the emission characteristics.**

Keywords: biodiesel, neem methyl ester, variable compression ratio engine, emission, performance

I. Introduction

The limited availability and fast retreating resources of petroleum fuels, increasing day by day prices of crude oil, and environmental aspects are the reasons for the use of biodiesel obtained from vegetable oils as alternative to petro diesel. Methyl/Ethyl Esters of Vegetable oils offer almost the same output with slightly lower thermal efficiency when used in diesel engines. Reduction of tail pipe emissions plays a major role in the field of biodiesel application and also research aspect in engine development. The environmental protection and pollution norms of the application of biodiesel. The use of neat vegetable oils possess some problems when operated long run of the engines due to high viscosity, low volatility and poly-unsaturated character of vegetable oils.

The main problems are trumpet formation on the injectors, carbon deposits, oil ring sticking and thickening and gelling of lubricating oil as a result of contamination by the vegetable oils. In the present work, bio-diesel (Methyl Ester) is prepared from Neem oil. The fuel properties of the test bio-diesel were determined and their performance and emission were studied on a four-stroke, single cylinder, variable compression ratio direct-injection diesel engine to evaluate suitability as alternative to Diesel.

II. Equipment and Experiments

A. *Bio diesel (Neem Methyl Ester)*

The Pure diesel used in the Experimentation is obtained from nearest filling station. The biodiesel prepared from Neem oil by a method of alkaline catalysed transesterification. The lower calorific value of biodiesel is approximately 7 % lower than that of pure diesel. The viscosity of Neem methyl ester is evidently higher than the pure diesel. In the experimentation, four compression ratios are provided by the screw adjustment for the test engine starting 17.5:1 for pure diesel run at particular compression ratio. Transesterification of Neem 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 traces. The NeME so produced was used for the experimentation along with pure diesel at above said compression ratios for comparative study. Fuel properties such as flash point, fire point, kinematic viscosity and calorific value were determined for Neem methyl ester and are compared with the pure diesel.

III. Bio-Diesel Preparation

A. *Two step acid base catalyzed transesterification*

Crude neem oil when transesterified using NaOH catalyst produced a significant amount of soaps from saponification side reaction. This was due to the high level of free fatty acids and small quantity of moisture in the crude neem oil. Therefore, a twostep process acid catalyzed esterification followed by alkali catalyzed transesterification was employed according to the method of Berchmans and Hirata (2008) [3].

B. *Acid pre-treatment (acid catalyzed esterification)*

Fig. 1. Magnetic stirrer with the neem oil

The method of acid transesterification is listed below:
1) The crude neem oil of 200ml is taken
2) It is heated at 60°C for about 10 min and mixed with 60 ml of methanol

3) To the mixture 2ml of concentrated $H_2SO_4$was added.
4) Then the mixture was stirred on magnetic hot plate for 1 h at 50°C
5) It was allowed to settle for 2 h.
6) The pre-treated oil was separated from the methanol - water phase at the top.

C. Base catalyzed transesterification:

The method of base catalysed transesterification is listed below

1) The pre-treated oil was measured (200ml) and taken in beaker.
2) Methanol of 50 ml was taken and added to it.
3) The mixture is heated on the magnetic stirrer at a temperature of 60° C.
4) The agitation rate is kept at 1000 rpm.
5) A solution of NaOH in methanol (1%) was dissolved at room temperature and the pre-treated oil was added.
6) The reaction was allowed for a period of 2hrs.
7) The resulting mixture was poured into a separating funnel and allowed to settle under gravity for 24 h for separation of biodiesel.
8) The lower glycerol layer was tapped off.

Fig. 2. Biodiesel in separating funnel

IV. EXPERIMENTAL INVESTIGATION

Fig. 3. Experimental setup

The specifications of the engine are as stated as below.

TABLE I
SPECIFICATIONS OF THE ENGINE

Engine	**4 stroke, Variable compression diesel engine**
No. of cylinders	Single cylinder
Cooling media	Water cooled
Rated capacity	3.5 kW @ 1500 RPM
Cylinder diameter	87.5 mm
Stroke length	110 mm
Connecting rod length	234 mm
Compression ratio	12:1-18:1
Orifice diameter	20 mm
Dynamometer	Eddy current

TABLE II
PROPERTIES OF DIESEL AND NEME

Properties	Diesel	Biodiesel (NeME)
Density(kg/m^3)	860	910
Kinematic viscosity at 40°c (Cst)	3.03	4.6
Calorific value (kj/kg)	42500	39000
Cetane number	48	50
Flash point ◦C	84	124
Surface tension N/m at 20°C	0.023	0.024
Molecular weight	170	205
Stoichiometric air to fuel ratio Wt/wt	15	13.5
Boiling point ◦C	188-344	-
Carbon content % weight	84-87	-
Oxygen content (%) weight	0	10

A. 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.

TABLE III
DETAILED SPECIFICATION OF THE ENGINE

Product	Research Engine test setup 1 cylinder, 4
Engine	stroke, Multifuel, VCR, Code 240
	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 dimensions	W 2000 x D 2500 x H 1500 mm

B. 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 setup which 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. 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, and NO, from the exhaust gas analyzer, which is shown in Fig were noted and recorded.

V. Results and Discussion

A. Specific fuel consumption

Specific fuel consumption at different loads with all percentage of blending was found slightly decreased because of extra oxygen present in the blend is taking part in combustion process. Due to which extra amount of fuel is burning inside cylinder which improves the efficiency which results decreased specific fuel consumption. Esterification also helps to lower the temperature reaction and viscosity of fuel which results the better combustion. As increase the brake power, specific fuel consumption is decreasing for all the blends because of brake power is increasing due to better combustion which may be attributed to extra oxygen present in the blend and specific fuel consumption is quantity of fuel burned inside the cylinder for unit brake power. As we increase the percentage of biodiesel, viscosity starts playing the important role in combustion. Because of higher viscosity, fuel will not be able to atomize well inside the combustion chamber and results in poor combustion efficiency. Due to this, in B-30 blend specific fuel consumption just start increasing because of viscosity comes into the picture at this moment. In B-10 and B-20, viscosity is not predominant. It is found that B-20 is having lower specific fuel.

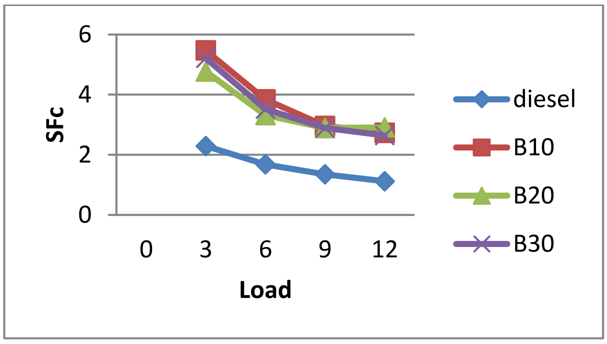

Fig. 4. Load vs. SFc

B. Brake thermal efficiency

An increase in break thermal efficiency may be attributed to the complete combustion of fuel because of oxygen present in blends perhaps also helped in complete combustion of fuel. It was observed that brake thermal efficiency of B10 is very close to brake thermal efficiency of diesel. Brake Thermal efficiency of B20 is better than B10 due to the more oxygen content. It is found that slight drop in efficiency of B30 because of improper combustion which may be attributed to higher viscosity than B10 and B20. Because of higher viscosity which may lead to poor mixture formation.

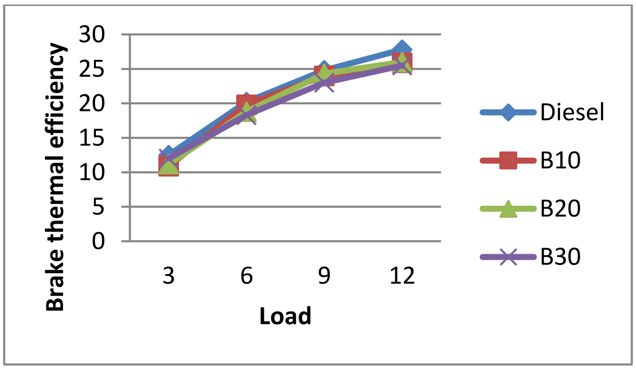

Fig. 5. Load vs. Brake thermal efficiency

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C. Hydrocarbon

Hydrocarbons were calculated by emission test for various blends of biodiesel and diesel. Quantity of hydrocarbon shows that the how the engine is performing throughout the operating range. If hydrocarbon quantity is more than engine is not performing well at this moment which means that incomplete combustion is happening inside the cylinder. Biodiesel gives fewer hydrocarbons compared to pure diesel. For B10 and B20 percentage of hydrocarbons decreases because of better combustion which may be attributed to extra oxygen present in the blend, but for B30 the percentage of hydrocarbons increases slightly due to insufficient combustion because of higher viscosity which may lead to poor mixture formation due to poor atomization.

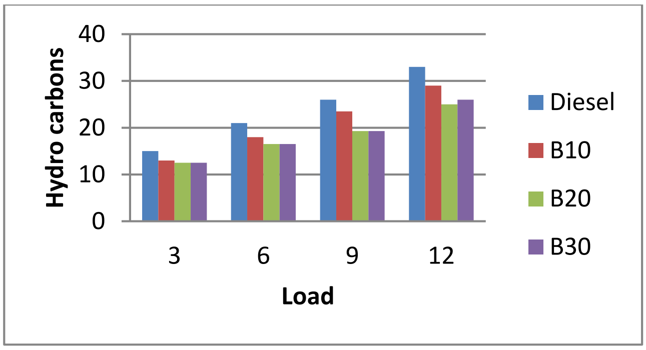


Fig. 6. Load vs. Hydro carbons

D. Carbon monoxide

Carbon monoxide was calculated by emission test for various blends of biodiesel and diesel. It also shows that the performance of engine. If the engine performs well than defiantly co emission will be less. In the presence of less oxygen, co will generate in the cylinder. Biodiesel produce less carbon monoxide than compare to pure diesel because of better combustion because extra oxygen present in the blend. When percentage of blend of biodiesel increases, carbon monoxide decreases because of extra oxygen present in the blend which may lead to better combustion. But we found slight increase in carbon monoxide in B30 because of insufficient combustion. This may be attributed to higher viscosity which may lead to poor mixture formation.

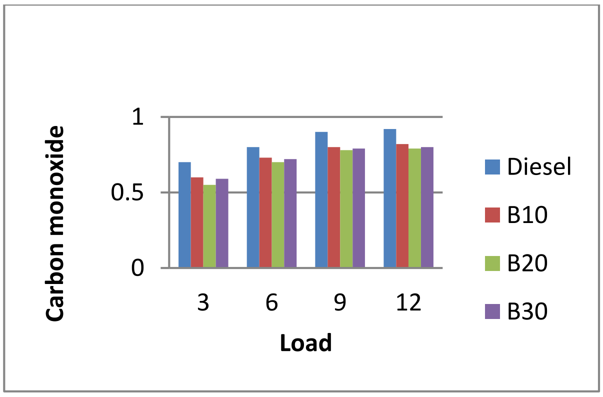


Fig. 7. Load vs. Carbon monoxide

E. NOx

NOx was calculated by emission test for various blends of biodiesel and diesel. At higher temperature nitrogen will combined with oxygen and produce the oxides of nitrogen. Biodiesel gives more oxides of nitrogen as compared to pure diesel because of extra oxygen present in the blend which may lead to better combustion results higher temperature which is responsible for generating the oxides of nitrogen. One more reason for generating the oxides of nitrogen is after burning because in C.I. Engine combustion will continue till to the end of the expansion process. Those particles of fuel which are taking part in the combustion process at the end of the expansion process is not producing any work. This can generate higher temperature in exhaust where there is chance for generating the oxides of nitrogen. When percentage of blend of biodiesel increases, nox increases because oxygen present in the blend perhaps also helped in complete combustion of fuel. But it is found that slight decrease in Nox in B30 because of incomplete combustion. This may be attributed to higher viscosity which may lead to poor mixture formation.

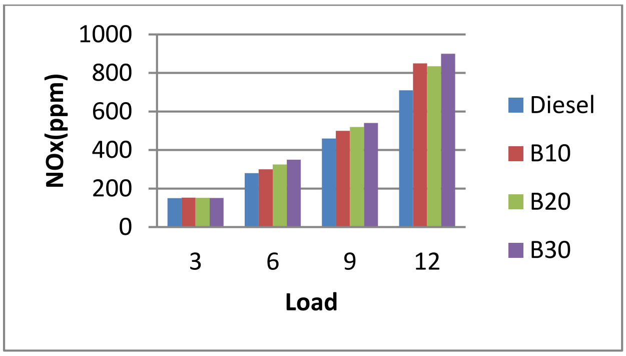
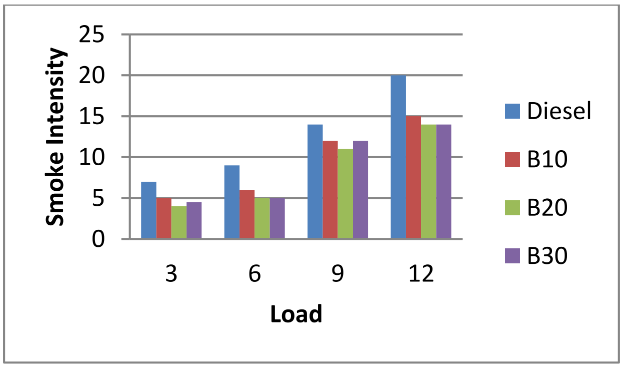


Fig. 8. Load vs. NOx

F. Smoke intensity



Smoke intensity was calculated by opacity test for various blends of biodiesel and diesel. Biodiesel gives less smoke density compared to pure diesel. When percentage of blend of biodiesel increases, smoke intensity decreases because oxygen present in the blend perhaps also helped in complete combustion of fuel. But we found that slight increase in smoke intensity in B30 because of incomplete combustion. This may be attributed to higher viscosity which may lead to poor mixture formation.

VI. Conclusion

From the experimental observations it is concluded that

1) The brake thermal efficiency of the CI engine increases with the compression ratio but its value was less when compared to that of the diesel.
2) Brake specific fuel consumption was good when increasing the compression ratio.
3) The emissions such as carbon monoxide and unburnt hydro carbons decreases with the blend ratio and compression ratio
4) The smoke decreases with the compression ratio and increases with the blend ratio.
5) Nitrous oxide emissions increases with the compression ratio and blend ratio.

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