RESEARCH PAPER | Engineering | Volume : 3 | Issue : 8 | Aug 2013 | ISSN - 2249-555X

Exhaust Emission Analysis and Performance Optimization of A Direct Injection Diesel Engine Fueling Diesel and Its Blends With Rapeseed Oil

KEYWORDS: Alternate Fuel, Rapeseed oil, Bio diesel

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ABSTRACT *This paper presents experimental results of combustion and exhaust emission characteristics of rapeseed oil and its blends with diesel. A 10 HP, 4 stroke 4 cylinder direct injection diesel engine was tested with rapeseed oil biodiesel and its blends to compare with conventional diesel fuel for different parameters. For this experimental work, different fuels namely diesel, 80:20, 60:40, 40:60 and 20:80 (v/v) blends of diesel fuel: Rapeseed Oil Biodiesel and neat Rapeseed biodiesel were prepared and tested for the performance and exhaust emission. Various parameters like Specific Fuel consumption, Brake Thermal Efficiency, Exhaust Gas Temperature, Smoke density, Carbon monoxide emission (CO) and Total unburned hydrocarbon emission (HC) were measured. The differences in the performance and exhaust emissions of these fuel blends when working with neat rapeseed oil biodiesel or its bio-diesel blends were compared.*

1. Introduction

Diesel engines have been widely used for automobiles engineering machinery, shipping equipments, power generation because of their excellent drivability and thermal efficiency. In our country the ratio of diesel to gasoline fuel is 7:1, depicting a highly skewed situation. Thus, it is necessary to replace fossil diesel fuel by alternative fuels. Fatty acid methyl esters, also known as "biodiesel" have been shown to have a great deal of potential as petro-diesel substitutes. Biodiesel comprise a renewable alternative energy source, the development of which would clearly reduce global dependence on petroleum, and would also help to reduce air pollution.

2. Rapeseed Oil Analysis

Fatty acid composition for Rapeseed Oil :

Palmitic Acid : 4 %
Oleic acid : 61 %
Linoleic acid : 21%
Alpha-linolenic acid : 11%
Saturated fatty acids : 7 %
Trans fat : 0.4 %
Stearic Acid : 1.8 %
Arachidic Acid : 0.7 %
Behenic Acid : 0.4 %
Lignoceric Acid : 0.2 %

The chemical analysis of Rapeseed Oil :

Acid Content :2mg KOH/g
Ash (%) : 0.01
Water Content (%) : 0.075
Sulfur Content : 20 mg/kg
Carbon residue (%) : 0.40
Refractive index (At 20°C) : 1.4726

3. Properties

The comparison of Physical and Chemical properties of Rapeseed biodiesel and standard specifications of diesel oil is shown in Table 1.

Table 1: Comparison of Physical and Chemical Properties of Rapeseed oil and Diesel oil

Property	RAPESEED OIL	Diesel Oil
Viscosity (cp) 30°C	4.2	3.06
Specific Gravity (15°C/4°C)	0.924	0.841/0.85
Cetane Value	47.7	47.8 to 59
Flash point (°C)	305.4	80
Carbon Residue (%)	0.40	<0.05 to <0.15
Distillation (°C)	643°C	<350 to <370

4. Experimental Setup

In tune of the scope and objectives of the experiment an experimental setup was prepared consisting of a four stroke, four cylinder diesel engine coupled to hydraulic dynamometer and arrangements for measurement of fuels consumption. Specifications and other details of different components of the setup are as state pointing sideways, fuel from the burette flows to the engine and by measuring the time taken for the specific amount of fuel to flow from burette, fuel consumption is calculated. Air consumption is measured by using an air box which is fitted with a standard office and U-tube water manometer that measures the pressure inside the tank.

4.1 Engine Specifications

The specifications of the test engine are as follows :

Make : Hindustan Motors. (Altech Industries, Coimbatore)
Type of Engine : Compression Ignition, 4 Stroke, 4 Cylinder, Water Cooled
Cubic Capacity :1500 cc
Rate of Output : 10.0 HP @ 1500 RPM
Fuel Used: High Speed Diesel Oil
Lubrication : Partly force lubrication and partly splash lubrication

The engine was tested with no load, 3kg, 6kg, 9kg and 12kg (Max) load. The speed of the engine was 1500 RPM and it was constant throughout the experiments.

4.2 Speed Measurement

Engine speed is measured by using tachometer which ranges from 0 to 10000 RPM, with the accuracy of +/- 10 RPM.

4.3 Temperature Measurement

Temperature measured included air inlet temperature, the engine exhaust temperature, cooling water inlet and outlet temperature, calorimeter inlet and outlet temperature and ambient temperature. A multi channel digital temperature indicator is used to read the temperatures of the exhaust gas and cooling water inlet and outlet thermocouples. The

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thermocouples are fitted on wells provided in the pipe lines.

4.4 Fuel Consumption
Fuel consumption is measured by means of the burette and a three way cock which regulates the fuel flow from the tank to the engine. When the lever is pointing upwards, fuel flows directly from the tank to the engine. When it is pointing sideways, fuel from the burette flows to the engine and by measuring the time taken for the specific amount of fuel to flow from the burette, fuel consumption is calculated.

4.5 Hydraulic Dynamometer
This dynamometer is very extensively used for testing engine for brake power measurement. Water Pressure of 5 kgf/cm^2 is maintained throughout testing.

4.6 Measurement of Exhaust Emission
Engine exhaust emission measurement is an important parameter indicating quality of combustion in the cylinder. Exhaust smoke level is measured using Exhaust Gas Analyzer. It measures HC (PPM) and CO%. The specification of Exhaust Gas Analyzer is briefly presented below:-

Make : Neptune.
Model : TD 2040/EGA 200 Digital Display.
CO : 0-30 % Range
Accuracy : Equivalent of normal Hexane.
Speed in response within 10 seconds for 90 % response.

4.7 Measurement Of Smoke Density
The main purpose of the smoke measurement is to quantify the smoke from the diesel engine. As the visibility is the main criterion in evaluating the intensity of smoke, development or principle of the smoke meter depends on the light obstruction be the smoke. Specifications of the Diesel Smoke meter used for the test purpose are as follows.

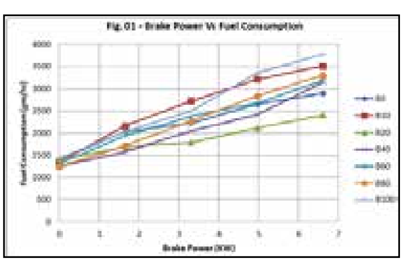
Make : Neptune.
Model : OPEX 2000 II / DX200P

5. Experimental Work
Following readings are to be taken for each load applied on the engine.

i. Speed of the engine (constant)
ii. Time in seconds for 100 cc fuel consumption
iii. DBT, WBT of ambient air
iv. Height difference between two limbs of U-tube water manometer (for measurement of air flow)
v. Cooling water inlet & outlet temperature and mass flow rate.
vi. Calorimeter inlet and outlet temperature
vii. Exhaust gas temperature
viii. Exhaust emission by Exhaust Gas Analyzer for HC and CO

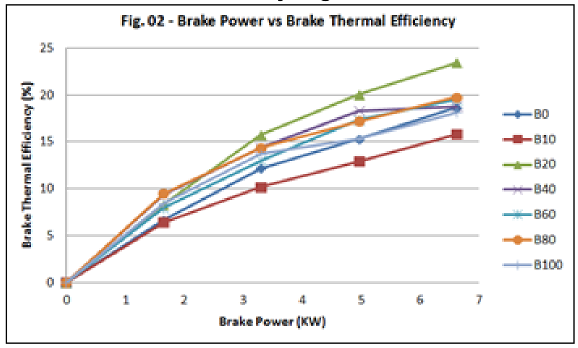
In this experimental work, the engine was operated on diesel fuel with different percentage of Bio Diesel that is B0, B10, B20, B40, B60, B80 and B100.

6. Effects on Performance Parameters
6.1 Specific Fuel Consumption (Fig. 01)



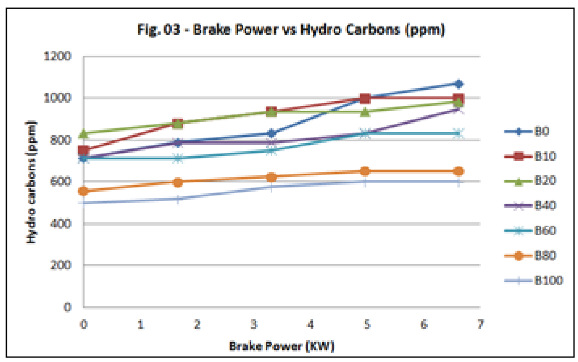
It is observed that the fuel consumption of conventional diesel increases from 1386.4954 gm/hr to 2906.3077 gm/hr when brake power increases from 0 to 6.6176 KW. Similar trend can be observed for B10, B20, B40, B60, B80, B100.

6.2 Brake Thermal Efficiency (Fig. 02)



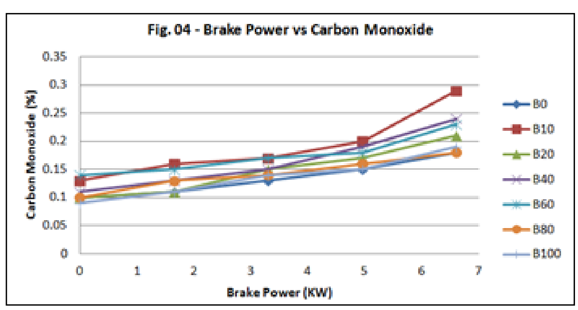
It is observed that B20 gives 9 to 11 % higher Brake Thermal Efficiency than the conventional diesel. It is observed that for a given load condition the maximum Brake Thermal Efficiency for B20 is 24 % compared to the maximum Brake Thermal Efficiency of 23 % for the conventional diesel. This may be because; Biodiesel contains little more oxygen resulting in better and efficient combustion.

6.3 Hydro Carbons (Fig. 03)



HC increases with increase in Brake Power. For the maximum load condition values of HC recorded are 1071, 1000, 985, 950, 833, 652, 600 PPM for B0, B10, B20, B40, B60, B80 & B100 respectively. Therefore it is concluded that increasing Biodiesel blends reduces the hydrocarbons.

6.4 Carbon Monoxides (Fig. 04)



CO for a given conditions are 0.18, 0.29, 0.21, 0.24, 0.23, 0.18 and 0.19 for B0, B10, B20, B40, B60, B80 & B100 respectively. It is further observed that B10 has maximum CO emission, which shows as poor blend capability. B20 has 33 % lower CO compared to B10 and can be used efficiently even for higher loading conditions.

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6.5 Exhaust Gas Outlet Temperature (Fig. 05)

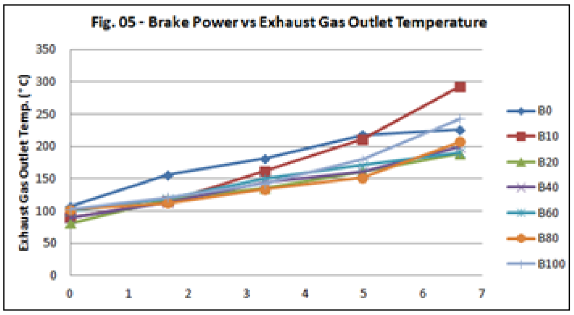

Fig. 05 - Brake Power vs Exhaust Gas Outlet Temperature

EGOT are 226, 293, 189, 199, 191, 207 & 243 °C for B0, B10, B20, B40, B60, B80 & B100 respectively. It is further observed that B20 has recorded EGOT of 189 °C compared to 226 °C of B0.

7. Conclusion

In the present study from the available results it is concluded that Mechanical Efficiency (Fig. 06) of the engine keeps on increasing by increasing the Biodiesel in Blends. The Mechanical efficiency for B100 is 61.6826 % and for B0 it is 53.9682 %. B20 gives 9 to 11 % higher Brake Thermal Efficiency than the conventional diesel fuel. B20 gives maximum Indicated Thermal Efficiency (Fig. 07) as 42.3882 % compared to the other values. This indicates that B20 has the best possible stoichiometric composition for perfect complete combustion. It is also observed that the fuel consumption of conventional diesel increases from 1386.4954 gm/hr to 2906.3077 gm/hr when brake power increases from 0 to 6.6176 KW. Similar trend is observed for B10, B20, B40, B60, B80, B100. The values of HC at maximum loading condition, are recorded as 1071, 1000, 985, 950, 833, 652, 600 PPM for B0, B10, B20, B40, B60, B80 & B100 respectively, that shows increasing Biodiesel blends reduces the hydrocarbons. Smoke Density (Fig. 08) is 31.5%, 29.8%, 27%, 24.5%, 23.1%, 21.7%, 20.3% respectively for conventional diesel, B10, B20, B40, B60, B80, B100. So, from the values available we can conclude that smoke density keeps on reducing by increasing the percentage of Rapeseed Oil Biodiesel in blends.

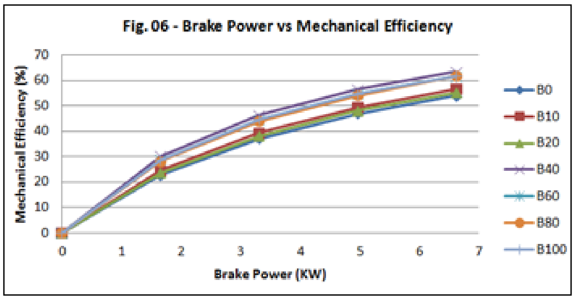

Fig. 06 - Brake Power vs Mechanical Efficiency

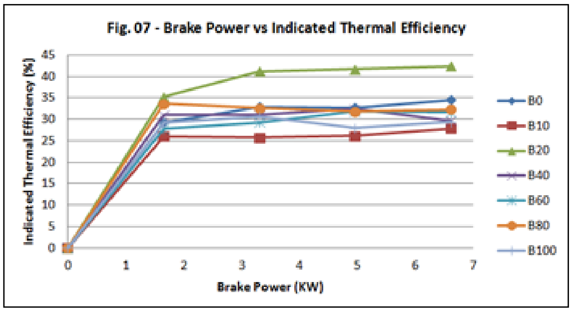

Fig. 07 - Brake Power vs Indicated Thermal Efficiency

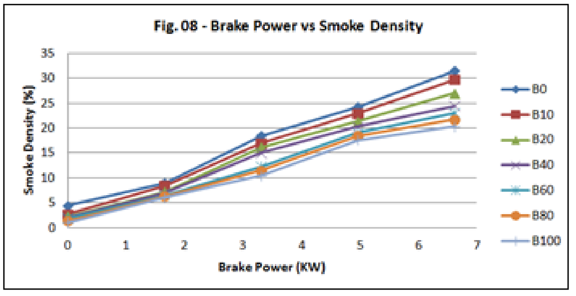

Fig. 08 - Brake Power vs Smoke Density

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