Performance, Combustion and Emissions of sunflower methyl esters / diesel blends in Air cooled diesel engine

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Abstract

In the present circumstance of fossil fuel crisis, the significance of alternative fuel investigates for diesel engines desires no emphasis. sunflower methyl esters can be used as alternative fuels to diesel since their properties are very close to diesel fuel, they are also renewable.Iin the present work, experiments have been carried out to assess the suitability of sunflower methyl esters as fuels in a diesel engine. In the present investigation tests were carried out on a 4.4 KW, single cylinder, direct injection, Air-cooled diesel engine.

Sunflower methyl esters used in the present investigation is mixed with diesel with different proportions (B00, B20, B40, B60, B80 and B100) as fuel in the diesel engine. The optimum results were found out from the above investigations and the performance , emissions and combustion analysis are carried out. Different graphs plotted are BP vs SFC, efficiencies, cylinder pressure vs crank angle(p-θ diagram) based on the combustion, emissions and performance analysis suitable conclusions are drawn and these results are presented as a paper.

Keywords: Diesel Engine, Performance, Combustion, Emissions, Alternative fuel.

1. INTRODUCTION

Petroleum based fuels are fuels stored in earth. There are limited reserves of these stored fuels & they are not renewable. With increasing power consumption and an increase in number of transport vehicles the coal pits are going to empty within short period. The world at present heavily depends upon petroleum fuels for transportation and for operating agriculture machinery. Diesel engines dominate the field of transportation and agriculture machinery on account of its superior fuel efficiency. The consumption of diesel in India is several times higher than that of petrol consumption. Roughly estimate of petrol and diesel consumption is 30% and 70%, respectively. Reserves appear to grow arithmetically while consumption is growing geometrically. Under this situation world will be leading to an industrial disaster [8].

The diesel engine is a major contributor to air pollution especially within cities and along urban traffic routes. In addition to air pollution that causes ground level ozone and smog in the atmosphere, diesel exhaust also contains particulate and hydrocarbon toxic air contaminants (TAC). Now society has become more aware of harmful effects of the various exhaust emission coming out of the engines and there is tremendous pressure on researchers to reduce exhaust emissions. Various harmful effects of exhaust emission are already established and known to today's society. Carbon monoxide, if inhaled, enters the blood stream and causes hypoxia, which leads to further health problems. Hydrocarbon emissions are irritant and odorants and some of them carcinogenic. Oxides of nitrogen are found to be responsible for many of the pulmonary diseases [1].

2. TRANSESTERIFICATION

Use of vegetable oils in diesel engines leads to slightly inferior performance and higher smoke emissions due to their higher viscosity and carbon residue. Filter plugging and cold starting along with higher specific consumption are observed while using vegetable oil due to their higher viscosity and lower calorific value [6] . The performance of vegetable oil can be improved by modifying vegetable oil by transesterification process. The process of converting the raw vegetable oil using methanol/ethanol in presence of catalyst like NaOH into biodiesel, which is fatty acid alkyl ester is termed as transesterification.

2.1 Procedure for preparation of Biodiesel from sunflower oil

sunflower oil is to be collected for further processing as bio diesel. The methodology developed / processes adopted for production of bio-diesel is given below. Whole process is described for one liter of sunflower oil. During processing of multiple quantity of sunflower oil, chemical constituents should be changed in the same proportion however timing for heating, settling and washing remain same.

- One liter of castor oil is to be taken.
- 300-330 ml of methanol & 10 ml of concentrated sulphuric acid is to be added to oil.
- The temperature of this mixture is to be set at 65-70 ^{0}C.
- This temperature of the mixture is to be maintained for about 6 hours and stirred continuously.
- The mixture is to be allowed to settle for 8 hours after completion of this reaction. This settled reactant mixture would consist of two layers.
  a) Upper layer as bio diesel and traces of glycerin etc.
  b) Bottom layer as glycerin and gums etc
- The glycerin is to be removed from the Bio-diesel preparation unit by opening the tap provided on the bottom.
- This pre washed bio diesel is taken in a separating funnel.
- 200 ml of hot water at approximately 40º C is added per liter of crude biodiesel and shaken well & allowed to settle to separate two layers for nearly 7-8 hours.
- Above process is repeated at least three times so that the traces of glycerin and soap get removed & the bio diesel produced from castor oil is ready for use.
- For adjusting viscosity esterified sunflower oil was further treated with mineral turpentine oil(M.T.O.).

Table 1 Properties of Sunflower oil

Property	Sunflower oil
Density (Kg/m^2)	916
Kinematic viscosity c.stokes	57.5
Flash point(^{0}c)	271
Fire point (^{0}c)	292
Heating Value KJ/Kg	35450
Specific gravity	0.91

Figure 1 Sunflower oil before esterification

Figure 2 Sunflower methyl ester (SFOME)

2.1 Fuel properties

Table 2 Fuel Properties

FUEL		**Property**			
		Specific gravity	**Calorific value (KJ/kg)**	**Kinematic Viscosity (mm^2/sec)**	**Flash Point °C**
Diesel		0.84	42700	3.02	55
SFOME	B20	0.845	41350	3.6	58
	B40	0.858	40120	4.12	62
	B60	0.868	38400	4.22	68
	B80	0.865	37500	6.45	105
	B100	0.861	36800	9.8	182

3. Experimental Procedure

Table 3 Specifications of CI Engine

Engine Type	**Four stroke, stationary, constant speed, direct injection, diesel engine**
Make	Kirloskar
Maximum Power	4.4 kW @ 1500 RPM
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Injection Timing	23.4^0 bTDC
Loading Type	Electrical Dynamometer

3.1 Description

Electrical swinging field dynamometer is used for measuring the brake power of the engine. This dynamometer is coupled to the engine by flexible coupling. The output power is directly obtained by measuring the reaction torque. Reaction force (torque) is measured by using a strain gauge type load cell. A water rheostat is used to dissipate the power produced. A panel board consisting of ammeter, voltmeter, switches and fuse, load cell indicator, digital rpm readout etc, is also provided.

3.2 Procedure

Before starting the experiments, all the equipment were calibrated according to the manufacturers' guidelines. The engine was started by hand cranking and was allowed to warm up at no load condition. The engine was fueled with methyl ester, traditional diesel and blends containing 20 percent, 40 percent, 60 percent and 80 percent of methyl ester. For every fuel change, the fuel lines were cleaned, and the engine was left to operate undisturbed for at least 30 minutes to stabilize on the new conditions. The following measurements were made at various loads (0%, 25%, 50%, 75% and 100% of rated load).

- Fuel consumption
- Air flow rate
- Engine output
- In cylinder pressure data
- Engine emissions

4. Performance Analysis

4.1 Brake Thermal Efficiency

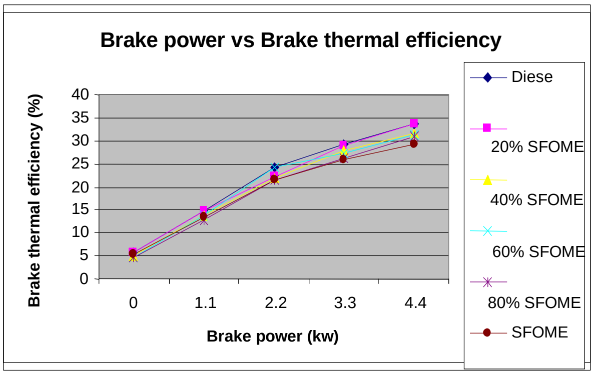

Figure 3 Brake thermal efficiency Vs Brake power

Figure.3 shows the variation of brake thermal efficiency with brake power for different biodiesel blends and diesel. The brake thermal efficiency is defined as the actual brake work per cycle divided by the amount of fuel chemical energy. From the figure it is observed that brake thermal efficiency increases with increase of load. But on increasing the blend percentage there is nominal decrease in the brake thermal efficiency. At higher loads, the brake thermal efficiency of biodiesel blends is lesser than diesel.

5. Emission Analysis

5.1 CO Emission

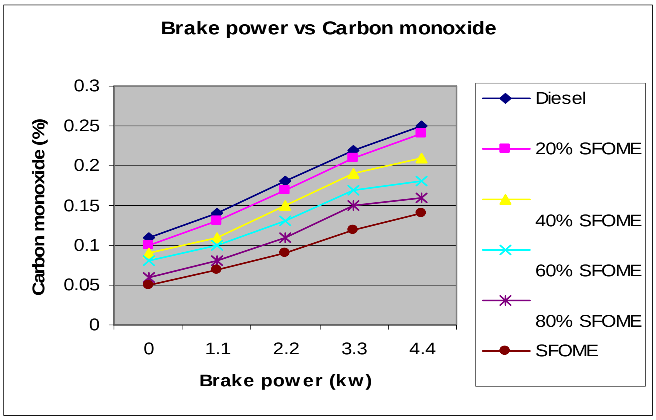

Figure 4 CO Vs Brake power

The CO emissions were found to be comparable at lower loads but at higher loads it is slightly higher than that of others. From the figure it is observed that the CO value is higher for the blend B20 from *Tamilvendhan.D et al.*

5.2 HC Emission (in PPM)

From figure.5 it is observed that hydro carbon (HC) increases with increasing load for all the blends of sunflower oil methyl esters.

The HC value gradually increases with increase in load. This is due to the increased amount of fuel injection at higher loads. While operating the engine with B40, the HC emission decreases significantly when comparing with other test fuels.

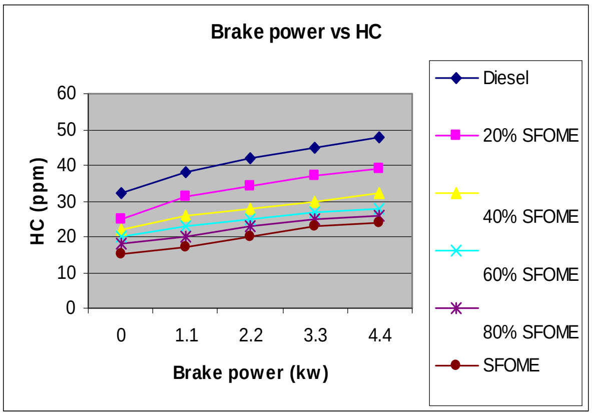

Figure 5 HC Vs Brake power

5.3 NOx Emission

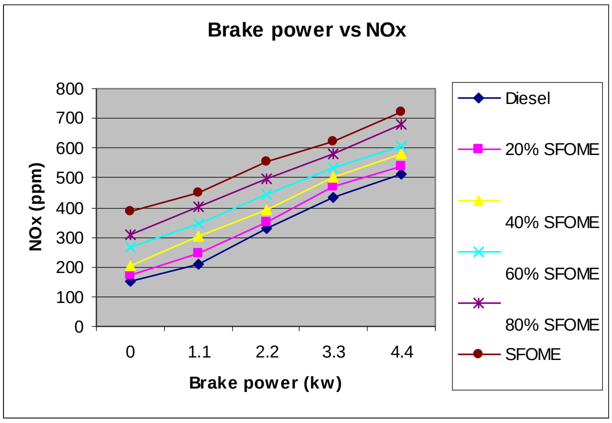

Figure 6 Nitrogen oxides Vs Brake power

Figure.6 shows the variation of NOx emission with respect to load. The NOx emission is almost same for all fuels at lower loads but at higher loads it is slightly higher than that of diesel fuel.

6. Combustion Characteristics

6.1 Variation of Cylinder Pressure

Figures .7 –11 show the variation of cylinder pressure with crank angle at rated power (4.4kW) for diesel, blends of 20%, 40%, 60% and 80% and 100% of SFOME respectively. All the fuels show the same trend except for slight changes in values of pressure at various crank angles. There are three distinct regions:

Region I (From the start of combustion to 4^0 bTDC): The cylinder pressure is higher for methyl ester and its blends compared to diesel. In this region, the cylinder pressure increases with the increase in percentage of methyl ester in the blend. This is due to the lower ignition delay of methyl ester and its blends. The combustion starts earlier and the motion of the piston towards TDC also helps the rise in gas pressure.

Region II (4^0 bTDC to 10^0 aTDC): In this region the cylinder pressure is lower for all the blends of methyl esters compared to diesel. This is mainly because of the lower heat release of methyl esters and its blends due to their lower calorific values. Since the specific heat capacity of exhaust gas of methyl ester operated engines is high compared to diesel (Suryawanshi et al, 2005), it absorbs more heat energy thereby reducing the high temperature and pressure of the gas in the cylinder.

Region III (after 10^0 aTDC): The methyl ester and its blends show slightly higher pressure in cylinder due to the late combustion of higher fatty acid components in methyl ester. For instance, the rise in pressure at 20^0 aTDC is 2.0%, 3.2%, 5.0%, 6.7% and 7.7% for 20%SFOME, 40% SFOME, 60% SFOME, 80% SFOME and SFOME compared to diesel.

It is also observed that the crank angle at which peak pressure occurs shifts away from TDC slightly. For example, the peak pressure at rated power (4.4kW) occurs at 6^0CA aTDC for diesel and 20%SFOME, 7^0CA aTDC for 40% SFOME and 8^0CA aTDC for 60% SFOME, 80% SFOME and SFOME.

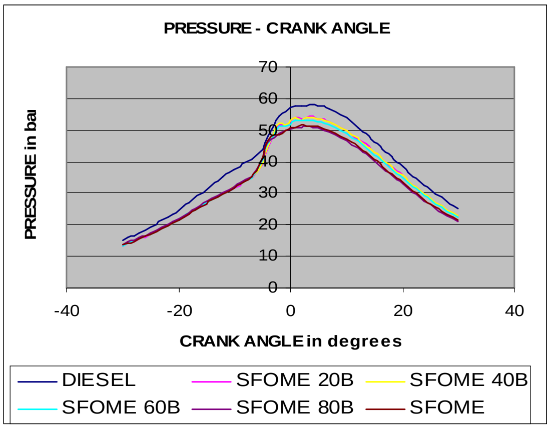

Figure 7 Pressure – crank angle diagram for SFOME and its blends at no load

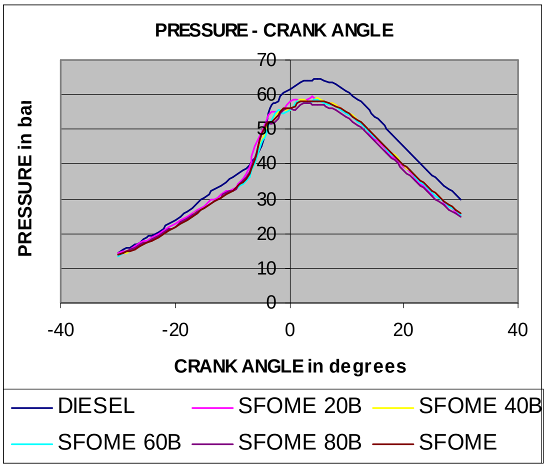

Figure 8 Pressure – crank angle diagram for SFOME and its blends at 25% load

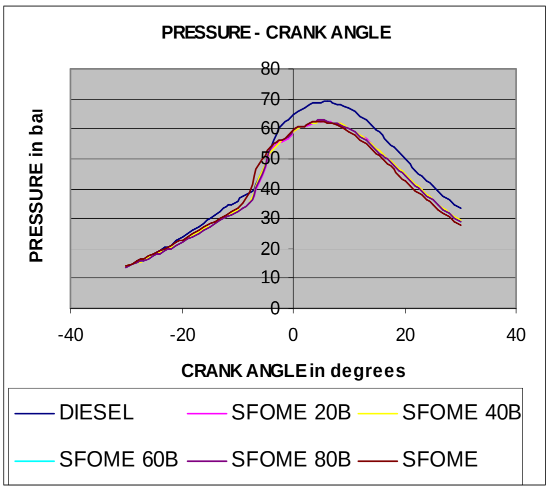

Figure 9 Pressure – crank angle diagram for SFOME and its blends at 50% load

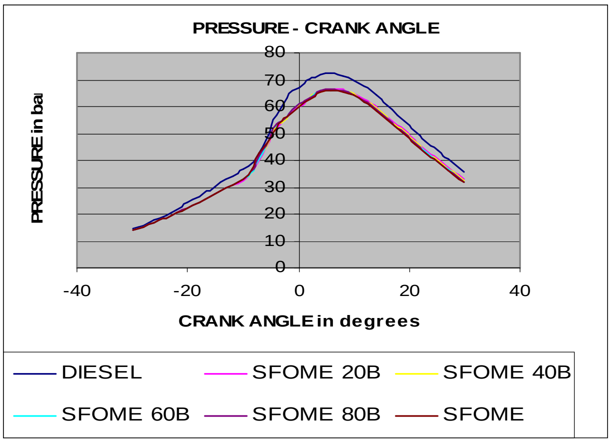

Figure 10 Pressure – crank angle diagram for SFOME and its blends at 75% load

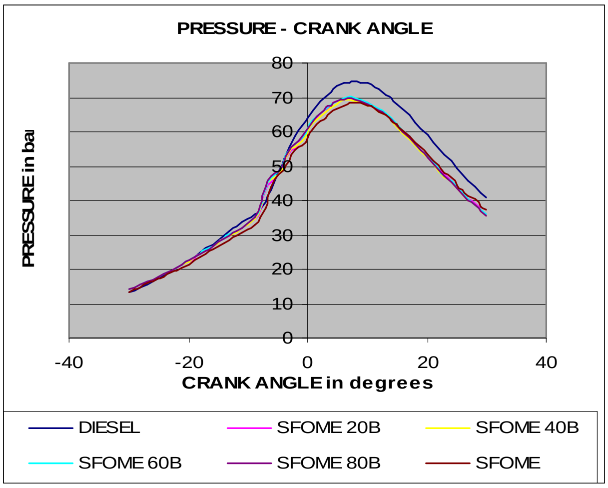

Figure 11 Pressure – crank angle diagram for SFOME and its blends at full load

7. Conclusion

The following conclusions are drawn from this work:

- Raw vegetable oils can be used as 100% replacement fuel for diesel fuel on a short-term basis. However long term engine durability studies show that 100% vegetable oil operation causes engine failures.
- The performance study of various biodiesel fuels and their blends as CI engine fuels indicates that no major modifications are required in the existing diesel engines.
- The effect of biodiesel on NO_x emissions depends on engine technology, its operating and maintenance conditions, testing methods, injection system and its calibration, etc.
- Many researchers observed drastic reduction in smoke emissions with biodiesel usage. This may be attributed to the presence of oxygen in fuel molecule, which contributes to promoting carbon oxidation, along with the substantial absence of aromatics and its higher cetane number.
- Biodiesel produced from sunflower is a viable substitute for petroleum diesel fuel. Its advantages are improved lubricity, higher cetane number, cleaner emissions, and reduced global warming.
- Experimental work carried out shows that the performance of SFOME fuel is on par with petroleum diesel fuel and emission characteristics of SFOME are much better than petroleum diesel fuel. Simultaneous reduction in NO_x level and smoke emissions are observed with SFOME blends.
- Increase in oxygen content in the SFOME-diesel blends as compared to diesel results in better combustion and increase in the combustion chamber temperature. This leads to increase in NO_X. SFOME recorded higher values of NO_X compared to diesel at rated load.
- Economic studies reveal that biodiesel is not an economic substitute for diesel oil at present. However, they are likely to become competitive when the fossil fuel reserves are depleted.

- In spite of all these, biodiesel and in particular SFOME, can be a valuable and interesting alternative diesel fuel due to its similar performance like diesel fuel and its better emission characteristics than diesel fuel.

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