Performance of Mustard Oil-Diesel Blend with Ethanol as an Additive in CI Engine

Martin Jose
Assistant Professor
Department of Mechanical Engineering
RIT Chennai (Mechanical)

Franklin Merlin. R
Assistant Professor
Department of Mechanical Engineering
RIT Chennai (Mechanical)

Abstract

This study is to determine the effect of the Ethanol as cetane number improves on combustion characteristics and pollutants of diesel engine fuelled by preheated biodiesel-diesel blend. A bench test is to be carried out on a four cylinder direct injection diesel engine aiming to study the variation of thermal efficiency, exhaust temperature and pollutant at different engine operating conditions.There are three blends chosen to be tested in the engine. It includes preheated B10 (900 ml diesel+100 ml Biodiesel), preheated B20 (800 ml diesel+200 ml biodiesel) and preheated B20E10 (700 ml diesel+200 ml biodiesel+100 ml ethanol). Hydrocarbon, CO2, NOx, emission characteristics are also studied in this paper with different blends of fuel.
Keywords: Bio-fuel, CO2, NOx, emission, oil-diesel blend

I. INTRODUCTION

In this century, it is believed that crude oil & petroleum products will become limited and expensive. Day-to-day, fuel economy of engine is getting improved and will continue to progress. However, massive increase in number of vehicles has started dictating the fuel demand. Gasoline and diesel fuels will become limited and very costly in the near future. Biodiesel is mainly comprised of mono-alkyl esters of long chain fatty acids and it was defined in standard ASTM D6751. Normally feedstock such as vegetable oil and animal fat is used to produce biodiesel through transesterification method. It may be used in any diesel automotive engine in its pure form or blended with some additives. The combustion characteristics of the biodiesel can be improved by blending it with oxygenated additives. The idea of using oxygenated compound is to carry out the clean burning. Cetane number can be improved by adding alcohol based 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. To reduce particulate emissions, fuel-compatible oxygen-bearing compounds should be blended to produce a composite fuel containing 10-25% v/v of oxygenate. Therefore, the composition of biodiesel and the use of additives directly affect properties such as density, viscosity, volatility, behaviour at low temperatures, and the ignition delay. That is why it is necessary to study the potential of biodiesel with oxygenated additives, as well as to study its feasibility, if it will be used as a viable alternative fuel in the future.

II. EXPERIMENTAL SETUP AND PROCEDURES

A. *Engine Specifications:*

The test engine used in this investigation was a Kirloskar TAF-1 Vertical, 4-Stroke cycle, single cylinder, totally enclosed, air cooled, and high speed compression ignition diesel engine. Table 1 lists the engine specifications and operating conditions used in this study.

The engine used is KirloskarTAF1 single cylinder, naturally aspirated, four stroke, air cooled, 17.5:1 compression ratio, diesel engine, and the maximum engine power is 4.4 kW at 1500 rpm. A Kirloskar A.C Alternator with resistance bank loading arrangement is also incorporated. The cylinder pressure was measured using a kistler 6613CA piezoelectric transducer with corresponding charge amplifier and data acquisition systems. Exhaust gas temperature were measured directly from the thermocouples (Cr–Al) attached to the corresponding passages. The engine exhausts NO, CO, HC, CO2 were measured with AVL- 444 Di gas analyzer, and the exhaust emissions were measured at 250 mm from the exhaust valve.

Table – 1
Specifications of Test Engine

Sl No	*Parameters*	*Value/dimension*
1	*Speed (rpm)*	*1500*
2	*Bore(mm)*	*87.5*
3	*Stroke (mm)*	*110*

4	*Rated brake power (KW @ 1500 rpm)*	*4.4*
5	*Compression ratio*	*17:1*
6	*Nozzle opening pressure(bar)*	*230*

A CLD Detector for NO emission, a Flame Ionization Detector (FID) analyzer for HC, a Non Dispersive Infrared (NDIR) analyzer For CO, CO2.The smoke opacity was measured by AVL-437C smoke meter after reducing the pressure and temperature in the expansion chamber. The performance and emission characteristics were evaluated for three trails and average are taken for analysis.

Fig. 1: Kirloskar Engine

III. MATHEMATIC MODELING

Power (P) : 46hp/4.4kW, 1500 rpm
Bore (d) : 87.5 mm
Stroke (L) : 110 mm
Calorific value : 37450 KJ/kg
Specific gravity : 0.8

A. IC Engine Formulae:

1. Total Fuel Consumption (TFC)

$$TFC = \frac{cc}{t_f} * S * 3.6 \text{ kg/hr} \quad (1)$$

Where, cc = Cubic centimetres
t_f = Time taken to consume 10cc of fuel measured in seconds.
S = Specific Gravity of Fuel Used (for mustard oil 0.5)
2. Indicated Power (IP)

$$IP = \frac{100*IMEP*L*N*A*K}{60*2} \text{ KW} \quad (2)$$

Where,
IMEP = Indicated Mean Effective Pressure in bar
L = Stroke Length (0.11) m
A = $\pi/4 * d^2$ m^2
K = Number of Cylinder
3. Brake Power

$$BP = IP - FP \text{ kW} \quad (3)$$

4. Torque Developed

$$T = \frac{60000*BP}{2*3.14*N} \text{ Nm} \quad (4)$$

Where, N = Engine Speed in rpm.
5. Brake Mean Effective Pressure (BMEP)

$$BMEP = \frac{60*2*BP}{100L*N*K*A} \text{ bar} \quad (5)$$

6. Specific Fuel Consumption (SFC)

$$SFC = \frac{TFC}{BP} \text{ kg/KWhr} \quad (6)$$

7. Mechanical Efficiency (η_m):

$$\eta_m = BP*100/IP\ \% \qquad (7)$$

8. Indicated Thermal Efficiency (ITE)

$$\eta_{ITE} = \frac{IP*3600}{TFC*CV} * 100\ \% \qquad (8)$$

9. Brake Thermal Efficiency (BTE):

$$\eta_{B} = \frac{BP*3600}{TFC*CV} * 100\ \% \qquad (9)$$

Where, CV = Calorific Value kJ/k

IV. RESULTS AND DISCUSSIONS

A. Performance Characteristics:

The TFC variation with respect to BP when tested with different blends in constant speed of 1500 rpm at all loading conditions are shown in figure 2. It observed that the fuel consumption for preheated B20E10 is lesser when compared to preheated B20.

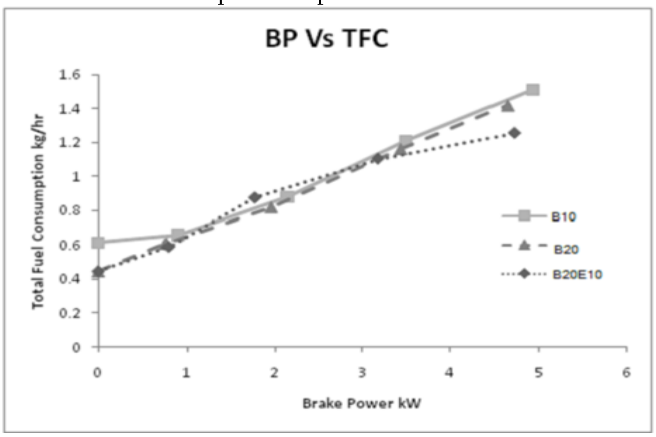

Fig. 2: Brake Power Vs Total Fuel Consumptions

Experimental observations revealed that brake power (BP) increases with total fuel consumption in all three blends at varied loading conditions. At the start, preheated B10 showed increased TFC to that of the other blends. However, preheated B20E10 showed lower TFC than the other blends.

The Variation of Brake Thermal Efficiency with respect to Brake power when tested with different blends in constant speed of 1500 rpm at all loading conditions is shown in figure 3. It is observed that efficiency is increased for preheated B20E10 blend when compared with other blends.

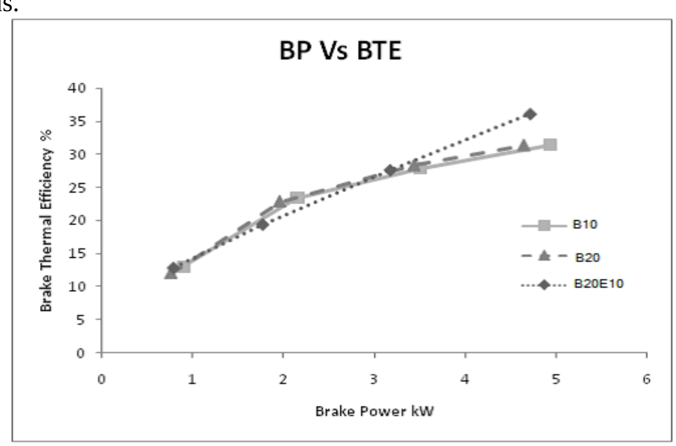

Fig. 3: Brake Power Vs Thermal Efficiency

Experimental observations revealed that brake power (BP) increases with brake thermal efficiency (BTE) in all three blends at varied loading conditions. On comparison with the three blends, BTE of B20E10 is found to be higher than preheated B20 by 4.7% and preheated B10 by 4.8%.

The Variation of Exhaust Gas Temperature (EGT)with respect to Brake power (BP)when tested with different blends in constant speed of 1500 rpm at all loading conditions are shown in figure 4.

Experimental observations revealed that among the three blends, Brake power (BP) increases with Exhaust Gas Temperature (EGT) at all loading conditions for all the three blends. However, preheated B20E10 showed lower total fuel consumption (TFC) which is lower than preheated B20 by about 4.2% and for preheated B10; it is lower by about 2%.

Ignition delay is the time difference measured in degree crank angle between start of injection and start of ignition of a fuel in diesel engine. The type of fuel is an important parameter affecting the ignition delay. The variation of the ignition delay for the various loading conditions is presented in Fig. 5. As the load increases the heat prevailing inside the cylinder increases and helps the air fuel mixture to ignite sooner, hence this trend is genuine. It can also be observed from the figure that the ignition delay is found to decrease. It is clear that blend with higher additive proportions have lesser ignition delay than the neat biodiesel. This is mainly because of the good self-ignitibility of cetane number improvers which has low bond dissociation energies and can easily generate the chain reaction initiator. The initiator promotes the chemical reaction, drawing a shorter ignition delay period.

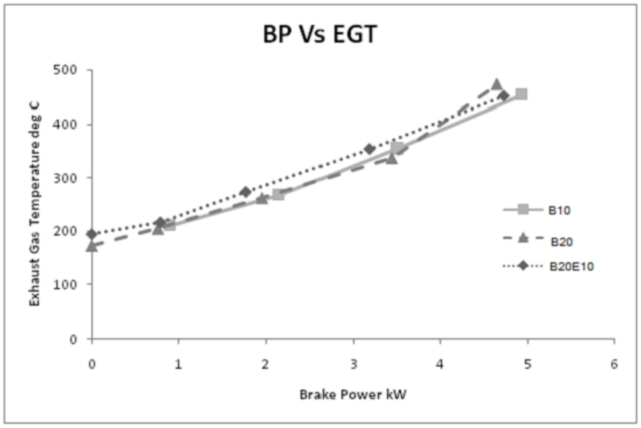

Fig. 4: Brake Power Vs Exhaust Gas Temperature

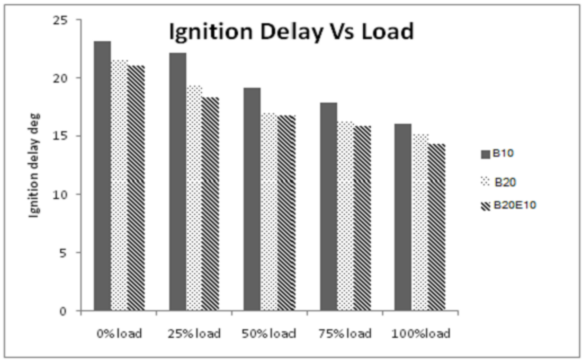

Fig. 5: Comparison Of Ignition Delay Period At Various Loads

It is observed that CO emission decreases with increasing additive proportion blend which is due to increase in cetane number that improves the self-ignitability of fuel. CO emissions for B20E10 were quite higher when compared to that ofother 2 blends.

Low amount of CO2 indicates the complete combustion of fuel in the combustion chamber and also relates to the exhaust gas temperature. The excess amount of CO2 in the atmosphere leads to global warming and environmental problems. These emitted CO2 are absorbed by the plants to maintain constant percentage in atmosphere. The variation of the CO2 emission for different Bio-diesel blends is shown in Figure 6. It is observed that there are no significant changes in emission level.

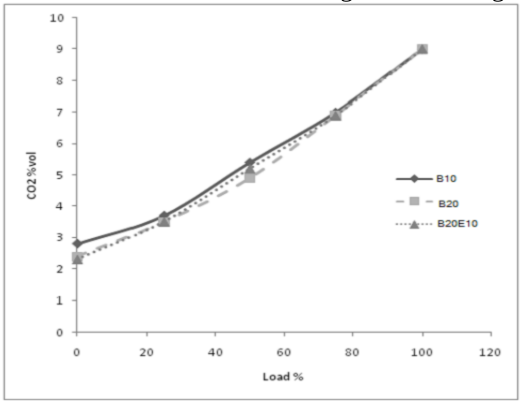

Fig. 6: Comparison Of CO2 Emission For Various Blends

The reason for the HC emission in a CI engine is wall deposit absorption, oil film absorption, crevice volume, incomplete combustion etc. During the combustion process HC particles condenses onto the surface of solid carbon soot. Most of this burned and only a small percentage of carbon soot comes out from the cylinder which contributes to the HC emission of the engine.

The variation of the unburned hydrocarbon emission for different Bio-diesel blends is shown in Figure 7. It is observed that HC emissions are reduced when ethanol proportion increases when compared with the three blends.

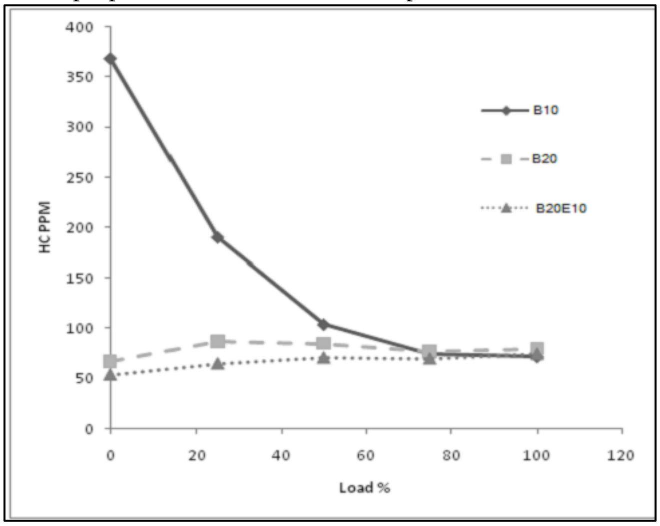

Fig. 7: Comparison Of Hydrocarbon Emission For Various Blends

The variation of the NO emission for various blends with different engine loads is shown in Fig. 8.The NO emission in a CI engine strongly depends on the combustion temperature and the oxygen availability. It is observed that NO emission is increased due to reduction in ignition delay and higher the cylinder temperature.

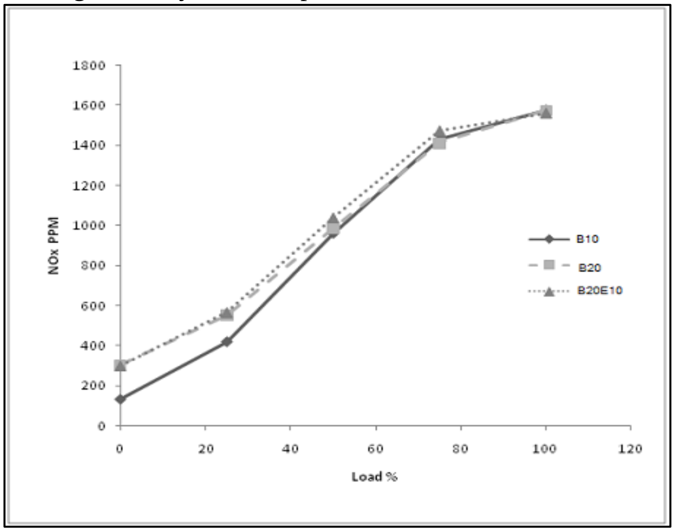

Fig. 8: Comparison Of Nox Emission For Various Blends

V. CONCLUSIONS

The performance and emission characteristics of a single cylinder, four strokes, air cooled, direct injection diesel engine having a power output of 4.4 kW at a constant speed of 1500 rpm, fueled with Preheated

B10, preheated B20 and preheated B20E10 have been analyzed and compared. It is found that the brake thermal efficiency (BTE) of preheated B20E10 is fairly superior to that of with preheated B20 and preheated

B10 due to decrease in viscosity and also resulted in lower total fuel consumption (TFC) of about 1.25 Kg/hr. Experimental outcome revealed that with decrease in viscosity of preheated B20E10, it showed improvement in engine emissions apart from CO. Oxides of nitrogen was found to be lower on comparison with the other blends during the trail. Smoke, NOx emissions from preheated B20E10 was lower than B10 and B20 during the whole experimental range. With preheated B20E10, the value of NOx, HC was further dropped and results showed that, emissions were found optimistic. The above conclusions were conducted in constant speed conditions and some deviations are anticipated at different engine speed.

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