Comparative Experimental Investigation Of Performance And Combustion Characteristics In A Single Cylinder Thermal Barrier Coated Diesel Engine Using Diesel And Neem Biodiesel

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Abstract

Diesel is a fossil fuel that is getting depleted at a fast rate. So an alternative fuel is necessary and a need of the hour. neem oil, which is cultivated in India at large scales, has a high potential to become an alternative fuel to replace diesel fuel. Direct use of neem oil cannot be done, as its viscosity is more than the diesel fuel, and hence affects the combustion characteristics. The neem oil is esterified to reduce the viscosity and it is blended with diesel on volume basis in different proportions. The use of thermal barrier coatings (TBCs) to increase the combustion temperature in diesel engines has been pursued for over 20 years. Increased combustion temperature can increase the efficiency of the engine, decrease. However, TBCs have not yet met with wide success in diesel engine applications because of various problems associated with the thermo-mechanical properties of the coating materials. Although, the in-cylinder temperatures that can be achieved by the application of ceramic coatings can be as high as 850-900^{0} C compared to current temperatures of 650-700^{0}C. The increase in the in-cylinder temperatures helped in better release of energy in the case of biodiesel fuels thereby reducing emissions at, almost the same performance as the diesel fuel. Here the effort has been made to determine the performance and combustion characteristics of NOME blend with diesel in conventional engine and LHR engine.

Key words: LHR Engine, normal engine Biodiesel, Neem oil, NOME, combustion Characteristics, Thermal barrier coating.

1. Introduction

Petroleum based fuels play a vital role in rapid depletion of conventional energy sources along with increasing demand and also major contributors of air pollutants. Major portion of today's energy demand in India is being met with fossil fuels. Hence it is high time that alternate fuels for engines should be derived from indigenous sources. As India is an agricultural country, there is a wide scope for the production of vegetable oils (both edible and non-edible) from different oil seeds. The present work focused only on non-edible oils as fuel for engines, as the edible oils are in great demand and far too expensive. The past work revealed that uses of vegetable oils for engines in place of diesel were investigated. Though the concerned researchers recommended the use of vegetable oils in diesel engines, there was no evidence of any practical vegetable oil source engines.

It is known that the efficiency of internal combustion diesel engines changes 38-42%. It is about 60% of the fuel energy dismissed from combustion chamber. To save energy, combustion chamber component are coated with low thermal conduction materials. The effect of thermal barrier coating on the cylinder components like piston crown top, cylinder liner, cylinder head inside and valves. The thermal barrier coated engines are otherwise known as low heat rejection (LHR) engines. Due to the insulation of the cylinder wall the heat transfer through the cylinder walls to the cooling system is reduced which change the combustion characteristics of the diesel engine. To know the changes during combustion the steady-state LHR engines operation have been studied by applying either the first or second law of thermodynamics. The state of the art of the thermal barrier coating is the plasma spray zirconia. In addition, other material systems have been investigated for the next generation of TBC. The study also focuses on coating method for Plasma Spray Zirconia (PSZ) to improve coating under high load and temperature cyclical conditions encountered in the real engine.

2. Properties of diesel fuel and NOME

The different properties of diesel fuel and NOME are determined and given in below table. After transisterification process the fuel properties like kinematic viscosity, CV, density, flash and fire point get improved in case of biodiesel. The calorific value of methyl ester is lower than that of diesel because of oxygen content. The flash and fire point temperature of biodiesel is higher than the pure diesel fuel this is beneficial by safety considerations which can be stored and transported without any risk.

Table 2.1 fuel properties

Properties	Diesel fuel	NOME
Kinematic viscosity at 40^0 C (cst)	4.1	5.93
Calorific value(KJ/Kg)	42000	39415
Density (Kg/m^3)	0.831	0.899
Flash point (^{0}C)	51	152
Fire point(^{0}C)	57	158

3. Experimentation

3.1 Engine components:

The various components of experimental set up are described below. Fig.3.1 shows line diagram of the experimental set up.

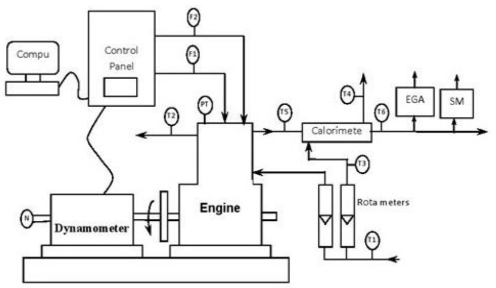

Fig-3.1 experimental set up

Table 3.1 Notation

PT	Pressure transducer
N	Rotary encoder
Wt	Weight
F1	Fuel flow
F2	Air flow
F3	Jacket water flow
F4	Calorimeter water flow
T1	Jacket water inlet temperature
T2	Jacket water outlet temperature
T3	Calorimeter water inlet temperature = T1
T4	Calorimeter water outlet temperature
T5	Exhaust gas to calorimeter temperature
T6	Exhaust gas from calorimeter temprature

Table 3.2 Engine specifications

Manufacturer	Kirloskar oil engines Ltd, India
Model	TV-SR, naturally aspirated
Engine	Single cylinder, DI
Bore/stroke	87.5mm/110mm
C.R.	16.5:1
speed	1500r/min, constant
Rated power	5.2kw
Working cycle	four stroke
Injection pressure	200bar/23 def TDC
Type of sensor	Piezo electric
Response time	4 micro seconds

4. Result and discussions

After detail study of performance and combustioncharacteristics of neem biodiesel and its blends in normal engine and low heat rejection engine it can be seen that 20% neem biodiesel blend and diesel are having same almost same characteristics so here the comparative analysis is carried out between normal engine and LHR engine.

4.1. Brake thermal efficiency:

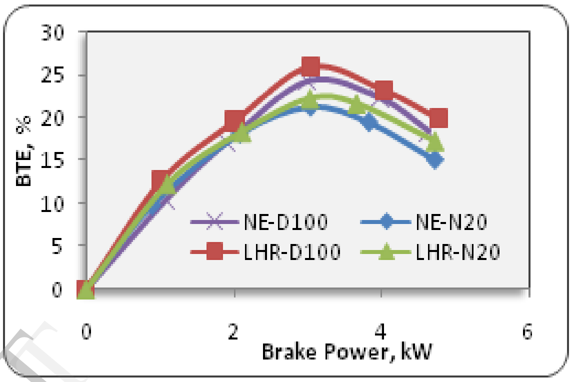

Fig.4.1 variation of brake thermal efficiency with different loads

Figure 4.1 shows the break thermal efficiency for neem biodiesel and its blends with respect to brake power for normal engine and low heat rejection engine. The maximum efficiency obtained in the case of LHR engine fueled with biodiesel at full load was lower than LHR engine fueled with diesel and higher than normal engine fueled with diesel and biodiesel. The efficiency of normal engine and LHR-N20 at full load are almost same this is due to complete combustion of fuel in thermal barrier coated engine. In overall, it is evident that, the thermal efficiency obtained in the case of LHR engine fueled with biodiesel is substantially good enough within the power output range of the test engine.

4.2. Specific fuel consumption:

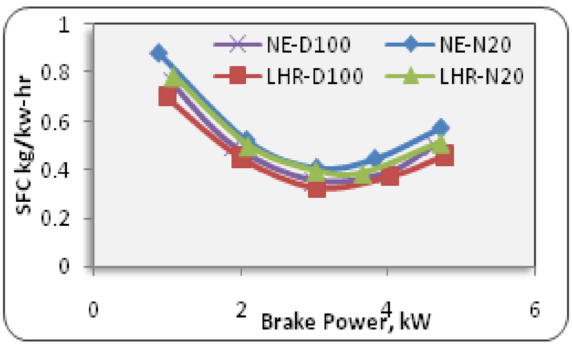

Fig.4.2 variation of specific fuel consumption with different loads

Figure 4.2 shows the specific fuel consumption for neem biodiesel and its blends with respect to brake power for both normal engine and LHR engine. At maximum load the specific fuel consumption of LHR engine fueled with biodiesel is higher than LHR engine fueled with diesel and lower than normal engine fueled with diesel and biodiesel. This higher fuel consumption was due to the combined effect of lower calorific value and high density of biodiesel. The test engine consumed additional biodiesel fuel in order to retain the same power output.

4.3.Mechanical efficiency:

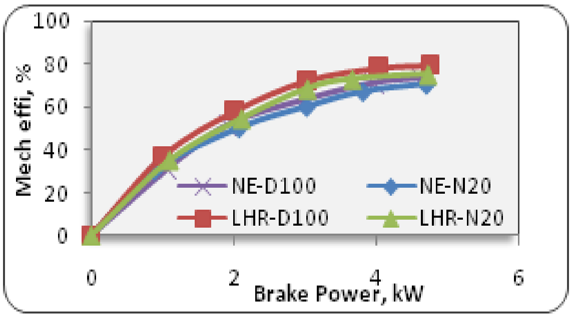

Fig.4.3 variation of mechanical efficiency with different loads

The variation of mechanical efficiency with brake power, for diesel and neem biodiesel blends are as shown in figure.4.3 for normal engine and LHR engine. The mechanical efficiency of diesel is slightly higher than the neem biodiesel in case of normal engine and similar case we can observe in LHR engine. From the graph it is evident that with increase in the concentration of neem biodiesel in diesel decreases the mechanical efficiency. Here we can see the effect of thermal barrier coating which increases the mechanical efficiency. At full load D100 and N20 in LHR has maximum efficiency of 79.45% and 75.12% respectively which are 6.1% and 4.6% higher than D100 and N20 of normal engine. This is due to fuel burning completely in LHR engine due increased temperature in combustion chamber.

4.4. Air-Fuel ratio

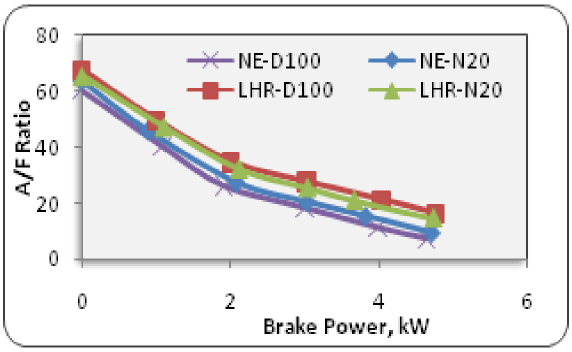

Fig.4.4 variation of air fuel ratio with different loads

The variation of air fuel ratio for diesel and 20% NOME blend is shown for both normal engine and LHR engine. Fuel consumption is higher in case of LHR engine due to increased temperature and completes combustion. Air fuel ratio decreases with increase in load because air fuel mixing process is affected by the difficulty in atomization of biodiesel due to its higher viscosity.

4.5. Indicated mean effective pressure

The variation of indicated mean effective pressure for diesel and 20% NOME blend is shown for both normal engine and LHR engine. Indicated mean effective pressure is low for NOME blend compared to diesel this is because of volatility and calorific value of NOME.

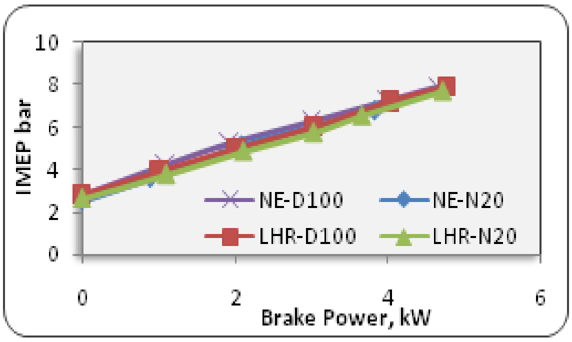

Fig.4.5 variation of IMEP with different loads

4.3.6. Exhaust gas temperature

The variation of exhaust gas temperature for diesel and 20% NOME blend is shown for both normal engine and LHR engine. When bio fuel concentration increases the exhaust temperature increases and as load increases the exhaust gas temperature increases due to thermal barrier coating the exhaust gas temperature increases

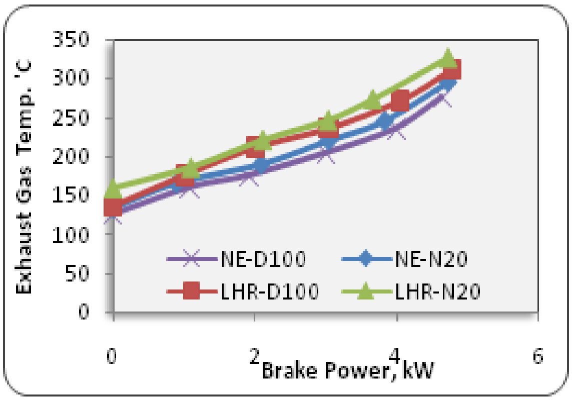

Fig.4.3.6 variation of exhaust gas temperature with different loads

4.7. Cylinder pressure v/s crank angle

In a CI engine the cylinder pressure is depends on the fuel-burning rate during the premixed burning phase, which in turn leads better combustion and heat release. Figure shows the typical variation of cylinder pressure with respect to crank angle. The cylinder pressure in the case of biodiesel fueled LHR engine is about 4.7 % lesser than the diesel fueled LHR engine and higher by about 1.64 % and 12.22% than conventional engine fueled with diesel and biodiesel. This reduction in the in cylinder pressure may be due to lower calorific value and slower combustion rates associated with biodiesel fueled LHR engine. However the cylinder pressure is relatively higher than the diesel engine fueled with diesel and biodiesel. It is noted that the maximum pressure obtained for LHR engine fueled with biodiesel was closer with TDC around 2 degree crank angle than LHR engine fueled with diesel. The fuel-burning rate in the early stage of combustion is higher in the case of biodiesel than the diesel fuel, which bring the peak pressure more closely to TDC.

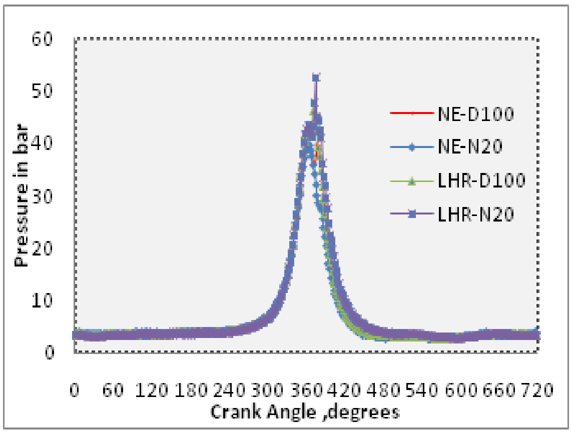

Fig.4.3.7 variation of cylinder pressure v/s crank angle

5. Conclusion

As detail study of performance and combustion characteristics of neem biodiesel and its blends on normal engine we can observe that 20% blend of neem biodiesel in diesel fuel has almost same mechanical efficiency, same specific fuel consumption and same indicated thermal efficiency .we can also see that there is slight increase in brake thermal efficiency which is a positive sign with this blend. In case of peak pressure we can see that there is almost same pressure as that of diesel fuel. So we can conclude that without any modification in engine we can save diesel fuel for certain extent without any compromise with standard performance and combustion characteristics and in future neem biodiesel can be a best alternative fuel which can replace the diesel.

As same parameters studied with engine modification, here we observed that there is increase in performance parameters than normal engine. There is increase in parameters like brake thermal efficiency, mechanical efficiency and brake mean effective pressure and there is decrease in specific fuel consumption, volumetric efficiency and fuel consumption which can be observed in comparative graph. There is also increase in peak pressure which higher than that of biodiesel with normal engine. With use of thermal barrier coating we can blend up to 40% which can help to conserve diesel fuel.

By studying performance and combustion characteristics on normal engine and low heat rejection engine it can concluded that with 20% blend we can achieve same characteristics as that of diesel fuel so N20 is the best blend and in future neem oil methyl ester can be a best and most suitable alternative fuel which can replace diesel fuel for years to come and with thermal barrier coating we can meet needy requirements.

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