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Performance, Emission and Combustion Characteristics of Neem Kernel Oil and its Biodiesel on a Low Heat Rejection Engine

Basavaraj M Shrigiri[1], Omprakash D Hebbal[2] and K Hema Chandra Reddy[1]
[1]JNT University, Anantapur, India.
[2]PDA College of Engineering, Kalburgi, India.

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ABSTRACT

The concept of the low heat rejection (LHR) is to suppress the heat rejection to the coolant and recovering this heat energy into useful work. The main objective of this work is to increase the performance of the engine and improve the fuel economy by coating piston face using metal matrix composite materials (MMCM). The neem kernel oil is selected as fuel, which has high viscosity, low volatility and low cetane number. In the present study, neem kernel oil (NKO) is converted into neem kernel oil methyl esters (NKOME) by transesterification process. The tests are conducted with NKO, NKOME and diesel on the coated and uncoated engines for different loads at rated speed. The combustion, emission and performance characteristics are determined and compared.

Introduction

Energy is essential input for the economic growth, social benefit and industrial development of the country. Since their exploration, the fossil fuels continued as the major source of energy. The decrease in fossil fuels, emission pollution produced by them and sharp escalation in fuel prices make biomass energy sources more attractive. Many of the developed countries have introduced new encouraging policies to bio fuels produced from non edible vegetable oils in transportation sector. The vegetable oils which are rich in oxygen can be used as alternative fuels for the operation of diesel engine [1].there are different types of biodiesels available such as sunflower, soyabean, cotton seed, lined, mahua, jatropha, pogamia etc [2]. Biodiesel is a fuel that is manufactured from vegetable oils with the help of catalysts, and may be directly used in diesel vehicles with little or no modification [3]. When biodiesel is used, HC, CO and PM ratios in exhaust emissions are lower, while sometimes very small NO_x increases occur [4]. Several methods exist for making vegetable oils usable in engines. The most significant is the transesterification method. In transesterification, vegetable oil is added to a mono hydroxyl alcohol (ethanol, methanol) in the presence of catalyst and the vegetable oil is broken into diesel fuel and glycerine; than that is reacted with triglyceride to form alcohol ester and glycerol [5].

Studies on engine materials and designs for ensuring efficient combustion of the fuel in the engines and decreasing pollutant emissions in the exhaust gases are continuing very rapidly. One area of the research is to coat combustion chambers with ceramic materials. In these engines, which are called adiabatic or low heat loss engines, the combustion temperature is increased by coating all or some of the combustion chamber with low thermal conductivity material. Thus combustion becomes more efficient and pollutant emissions are improved [6]. Kemo and Bryzik used thermally insulating materials such as silicon nitride for insulating different surfaces of the combustion chamber. An improvement of 7 % in the performance was observed [7]. In various studies, it has been reported that engine performance and exhaust emissions were improved in diesel engines where all or some elements of their combustion chambers were coated with ceramic [8,9].

The major purpose of this work is to investigate the effects of using biodiesel as an alternative fuel in a diesel engine that has its piston face coated with metal matrix composite materials, to determine any significant effects on performance, emissions and combustion. LHR engine fuelled with neem kernel oil methyl ester, neem kernel oil and normal diesel engine fuelled with diesel fuel are referred to by NKOME, NKO and NDE, respectively, throughout the paper.

Experimental test rig, instrumentation and programme

The engine used in this study is 5.2 kW, computerized Kirloskar make, single cylinder, four stroke, vertical, water cooled, direct injection diesel engine. The important engine specifications are given in Table 1. An eddy current dynamometer is used to load the test engine. Exhaust emission from the engine is measured with help of AVL DiTEST 1000 (Five gas analyzer) and smoke emission is measured with the help of AVL DiSMOKE 480 (Smoke meter).

Crude neem kernel oil is selected for the preparation of biodiesel. 3.5 grams of sodium hydroxide (NaOH) and 200 ml of methyl alcohol (CH_3OH) are used for esterification of 1 litre of neem kernel oil. The catalyst is dissolved in the alcohol then the alcohol-catalyst mixture is poured into the neem kernel oil which is heated and mixed thoroughly. The temperature of the neem kernel oil, alcohol and catalyst mixture is maintained at 60°C for an hour. When the transesterification is finished the mixture is taken into a separating funnel to settle. After the settlement of the biodiesel and the glycerine, the glycerine is drained. The biodiesel is washed thoroughly with pure water to remove alcohol and catalyst residue. After washing, the biodiesel is heated to a temperature of 110°C in order to remove the traces of water in the form of vapours. The properties of the diesel, neem kernel oil and its methyl ester are determined with the help of standard procedures. As can be seen from Table 2, the calorific value of NKOME is lower than that of diesel and other properties are higher than the diesel.

Tele:
E-mail addresses: shrigiri2007@gmail.com

Table 1: Specification of the test engine

Manufacturer	Kirloskar Oil Engines Ltd., India
Model	TV-SR II, naturally aspirated
Engine	Single cylinder, direct injection diesel engine
Bore/stroke/compression Ratio	87.5 mm/110 mm/ 17.5:1
Rated power	5.2 kW
Speed	1500 rpm, constant
Injection pressure/advance	200 bar/23 degree before TDC
Dynamometer	Eddy current
Type of starting	Manually
Air flow measurement	Air box with 'U' tube
Exhaust gas temperature	RTD thermocouple
Fuel flow measurement	Burette with digital stopwatch
Governor	Mechanical governing (Centrifugal type)
Sensor response	Piezo electric
Time sampling	4 micro seconds
Resolution crank	1 degree crank angle
Angle sensor	360° encoder with resolution of 1 degree

Table 2: Properties of the test fuels

Properties	Diesel	NKO	NKOME
Calorific value(kJ/kg)	42600	40219	41543
Density (kg/m^3)	831	930	896
Flash point (^{o}C)	51	245	160
Fire point(^{o}C)	57	262	175
Carbon residue (%)	00	1.28	0.399

The tests are conducted for variable brake power of 0%, 10% 25%, 50%, 75% and 100% at rated speed. First, diesel fuel is used as fuel in the normal engine. After completion of the test on normal engine, the piston is coated with plasma sprayed 100% zirconium oxide (ZrO_2) with a thickness of 0.1 mm over a 0.1 mm thickness of 50% ZrO_2+50% Al_2O_3 then which is coated over a 0.1 mm thickness of 25% ZrO_2+75% Al_2O_3 and finally this is coated over a 0.15 thickness of bond coat of nickel chromium (Ni-Cr), as the test engine is converted to a LHR condition. Then, the NKO and NKOME which have the properties given in Table 2 are used as fuel. After completion of the test on LHR engine, the results are compared.

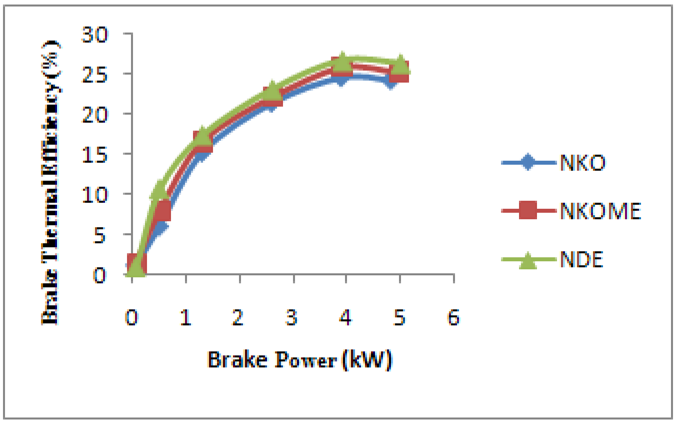

Figure 1.Variation of brake thermal efficiency with brake power

Results and discussions

The main objective of this work is to investigate the performance, emission and combustion characteristics of LHR engine fuelled with NKOME and NKO compared to that of NDE.

Performance analysis

Important engine performance parameters, such as brake thermal efficiency and specific fuel consumption for NKOME, NKO with NDE, are calculated, analyzed and graphically represented. The variation of brake thermal efficiency with brake power for NKOME, NKO and NDE are shown in Fig. 1. Brake thermal efficiency of NKOME is very close to NDE for the entire range of operation. Maximum brake thermal efficiency of NKOME is 25.83% against, 26.67% of NDE, which is lower by 0.84%. We can say that brake thermal efficiency of NKOME is well comparable with that of diesel. The maximum brake thermal efficiency of NKO is 24.66% against, 26.67 of diesel.

From Fig 2, it is observed that, NKOME and NKO have higher SFC as compared to NDE due to lower heating value. The SFC of NKOME at maximum load is greater than that of normal diesel engine at all brake power. The reason may be the differences in heating value and density between NKOME and normal diesel.

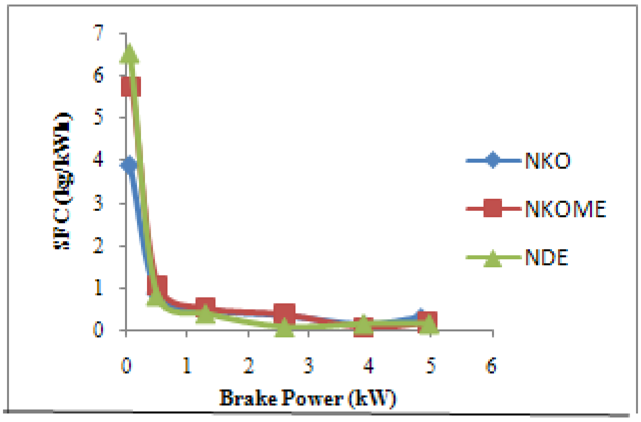

Figure 2.Variation of SFC with brake power.

Fig. 3 shows the variation of exhaust gas temperature with brake power for NKOME, NKO and NDE. It shows increasing exhaust temperature with increase in brake power for NKOME and NKO. The reason may be poor volatility and higher viscosity of these biofuels and higher flash points in NKOME and NKO than diesel. Those constituent having higher flash points are not adequately evaporated during the main combustion phase and continued to burn in the late combustion phase. This resulted in a slightly higher exhaust gas temperature (EGT).

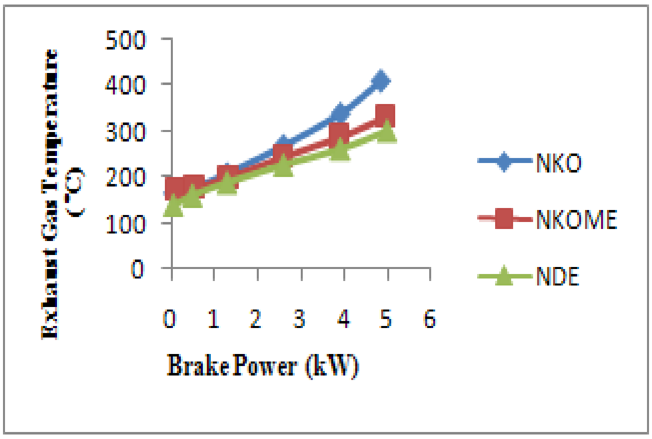

Figure 3.Variation of EGT with brake power.

Emission analysis

The effect of brake power on carbon monoxide is shown in Fig. 4. The carbon monoxide for NKOME and NKO is slightly higher than the normal diesel at all loads. It is seen that, the CO decreases with increasing brake power up to 75% load for all test oils. It is also observed that NKOME results in slight increment in a CO level when compared to the normal engine.

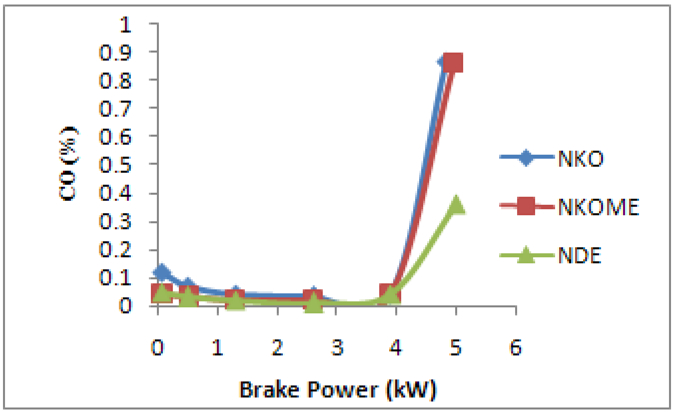

Figure 4.Variation of CO with brake power

Fig. 5 shows variation of hydrocarbons with brake power. It is seen that, unburned hydrocarbon (HC) emission for NKOME is close to NDE for the entire range of operation and NKO is higher than NDE. The effect of fuel viscosity on fuel spray quality would be expected to produce some HC increases with vegetable oils.

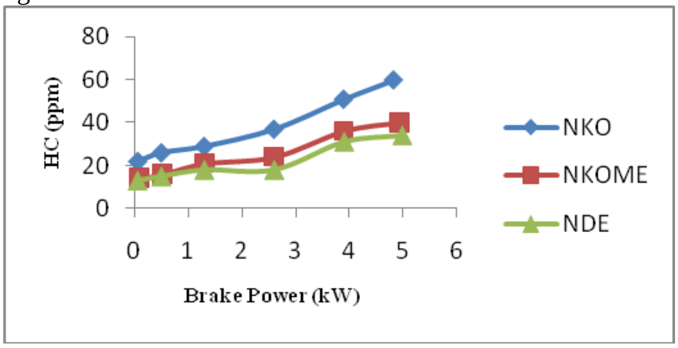

Figure 5.Variation of Hydrocarbon with brake power.

The variation of oxides of nitrogen with brake power is shown in Fig. 6. The NO_x for NKOME is very close to NDE up to 75% of loading and NKO is lower than NDE up to 75% loading. The maximum NO_x emission for NKOME and NKO is 673 ppm and 529 ppm respectively against 610 ppm of NDE at 75% loading.

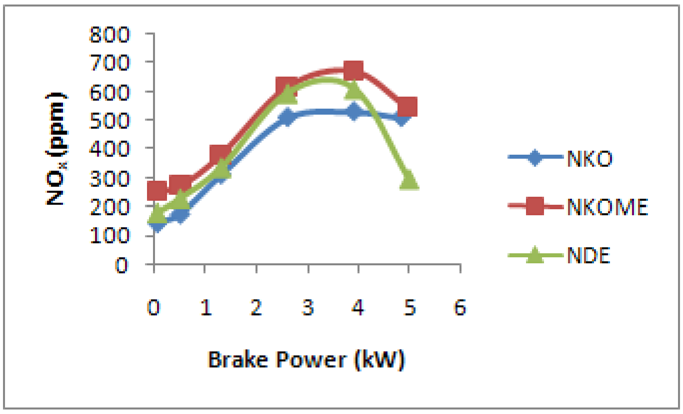

Figure 6.Variation of NOx with brake power.

Combustion analysis

Fig. 7 shows the variation of cylinder pressure with crank angle for all brake power at rated speed for NKOME, NKO and NDE. It is observed that, the peak pressure for the NKOME and NKO are 65.37 bar and 61.22 bar respectively and the peak pressure for the NDE is 64.9 bar. The cylinder peak pressure for NKOME is slightly higher than NDE whereas the cylinder peak pressure for NKO lower than NDE. It is observed that, the crank angle at which peak pressure occurs slightly shifts away from TDC i.e. for the peak pressure for NKOME occurred at 12^o CA after TDC, for NKO, it is 13^o CA after TDC and for NDE it is 13^o CA after TDC.

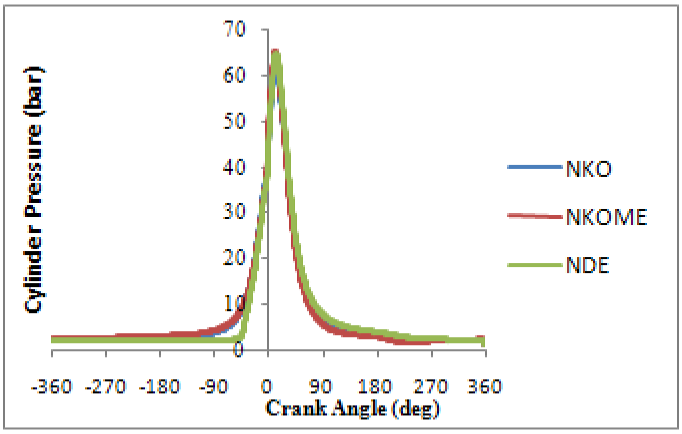

Figure 7. Variation of cylinder pressure with crank angle.

Fig. 8 shows variation of net heat release rate with crank angle for NKOME, NKO and NDE. The premixed burning phase associated with a high release rate is important for normal diesel engine and is responsible for the higher peak pressure and higher rates of pressure rise. This may be the reason for higher thermal efficiency with NDE. In NKOME and NKO there is significant increase in combustion rates during the later stage that has resulted to higher exhaust temperatures and lower thermal efficiency. The NKOME and NKO has reduced heat release rate compared to NDE.

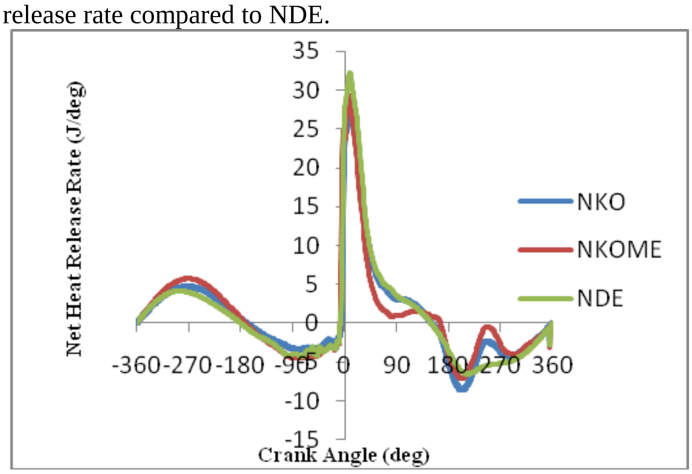

Figure 8. Variation of heat release rate with crank angle.

Conclusions

In this work, the piston face is coated with metal matrix composite materials. Neem kernel oil methyl ester (NKOME) and neem kernel oil (NKO) are used in coated engine and diesel is used for uncoated normal engine. The combustion, emission and performance characteristics of NKOME and NKO are analyzed and compared with that of normal engine fuelled with diesel. The summarized conclusions are as follows:

- The carbon monoxide emission for NKOME and NKO is almost same up to 3.9 kW of brake power and slight increase in CO after 3.9 kW of brake power than that of NDE.
- The unburned hydrocarbon emission for NKOME is 15 -20 % higher than NDE where as the hydrocarbon emission for NKO is 50-70 % higher than that of NDE.
- The oxides of nitrogen emission for NKOME are very close to NDE up to 75% of loading and for NKO it is lower than NDE up to 75% loading. The maximum NO_x emission for NKOME and NKO is 673 ppm and 529 ppm against 610 ppm of NDE at 75% loading.
- Brake thermal efficiency of NKOME is very close to NDE for the entire range of operation. Maximum brake thermal

efficiency of NKOME is 25.83% against, 26.67% of NDE, which is lower by 0.84%. We can say that brake thermal efficiency of NKOME is well comparable with diesel. The maximum brake thermal efficiency of NKO is 24.66% against, 26.67 of diesel.

- The specific fuel consumption of NKOME and NKO is almost same than that of NDE except for the range of 10 – 50 % of brake power.
- The cylinder pressure for NKOME is almost same as that of NDE and for NKO it is 5.73% less than that of NDE at 13^o CA after TDC.
- The heat release rate in NKO is slightly less than NDE and in case of NKOME; it is 10.12% less than that of NDE.

The above comparative study clearly reveals the possibility of using the biodiesel in LHR direct injection diesel engine. The combustion, performance and emission characteristics show the suitability of neem kernel oil biodiesel in LHR engine.

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